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EXPERIMENTS ON VEGETABLE SEED DISINFECTION AND OBSERVATIONS ON VARIETAL RESISTANCE OF BEANS, PEAS, AND SWEET CORN TO SOME DISEASES IN MANITOBA[1]

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INTRODUCTION

During World War II, Canadian supplies of vegetable seeds and seed disinfectants were abnormally low. At the same time, the greater interest in urban and rural gardening increased the demand for both seed and disinfectants. These circumstances gave rise to requests on the part of growers for information about the suitability of varieties as well as the effectiveness of certain seed disinfectants that had not heretofore been generally used for the treatment of vegetable seed. In the absence of such information there was a likelihood that much inferior seed, inadequately disinfected, would be sown, often with unsatisfactory results.

Up to the commencement of the present investigation, there was available very little experimental evidence regarding the value of vegetable seed disinfection under Manitoba conditions. A few market gardeners usually applied mercury or copper preparations to the seed in order to improve seedling stand in the greenhouse, but as a rule the only vegetable crop given this protection in the field was peas. Also, in most cases, the rate at which the disinfectant was applied was based upon recommendations made for other areas.

The objects of the present investigation, extending from 1942 to 1946, inclusive, were to determine (1) which of the newer seed disinfectants were suitable for the treatment of peas—a crop of increasing importance in Manitoba; (2) if the disinfectants used for cereal seed in Canada were suitable for vegetable seed; (3) what kinds of vegetable crops were most likely to benefit from seed treatment; and, (4) which varieties of beans, peas, and sweet corn were most resistant to the more common diseases of these crops in Manitoba.

VEGETABLE SEED DISINFECTION

Much has been written elsewhere regarding the value of seed disinfection and the relative merits of different disinfectants. A review of this literature shows that, as a rule, considerable variation in the response of individual crops may be expected. On the whole, treatment of vegetable seed appears to have been regarded as a sound practice, as it generally improved germination and controlled seed-borne diseases.

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TABLE 1.—EFFECT OF SOME SEED DISINFECTANTS ON GERMINATION AND YIELD IN RADIUM PEAS

Effect studied	Disinfectant	Dosage (oz. per bu.)	Seed lot used[1]				
			1943		1944	1945	
			1	2	3	4	5
			%	%	%	%	%
Germination	Control	0.0	51.7	46.2	88.0	69.5	48.2
	New Improved Ceresan	1.0	87.2	81.2	89.0	64.7	58.5
	New Improved Ceresan	1.5	88.0	86.1	93.1	70.7	54.0
	Half-ounce Leytosan	1.0	—	—	90.8	54.0	55.0
	Half-ounce Leytosan	1.5	—	—	88.6	56.0	61.0
	Spergon	1.0	—	—	90.8	55.2	55.7
	Spergon	2.0	62.2	70.1	90.6	67.2	54.7
	Spergon	3.0	—	—	89.6	—	—
	Arasan	1.0	—	—	91.1	70.5	56.2
	Arasan	1.5	75.0	71.0	—	64.2	54.5
	Arasan	2.0	—	—	88.6	—	—
	Arasan	3.0	—	—	91.6	—	—
	U.S.R. 604	2.0	85.4	80.5	—	—	—
	U.S.R. 2A5	0.5	—	—	—	52.2	51.7
	Necessary difference (5%)		13.9	13.9	DNS[2]	DNS	DNS
			gm.	gm.	gm.	gm.	gm.
Yield	Control	0.0	226	152	1287	1038	836
	New Improved Ceresan	1.0	200	222	1123	845	786
	New Improved Ceresan	1.5	225	215	1434	934	897
	Half-ounce Leytosan	1.0	—	—	868	701	851
	Half-ounce Leytosan	1.5	—	—	1029	690	798
	Spergon	1.0	—	—	1216	719	722
	Spergon	2.0	245	242	965	912	870
	Spergon	3.0	—	—	1377	—	—
	Arasan	1.0	—	—	997	816	762
	Arasan	1.5	240	207	—	905	799
	Arasan	2.0	—	—	945	—	—
	Arasan	3.0	—	—	1214	—	—
	U.S.R. 604	2.0	187	192	—	—	—
	U.S.R. 2A5	0.5	—	—	—	839	723
	Necessary difference (5%)		37.0	37.0	DNS	DNS	DNS

[1] Seed lots 1, 2, and 5 were obtained from commercial sources. Seed lots 3 and 4 were hand-threshed and were derived from lots 1 and 3, respectively.

[2] DNS = Difference not significant.

Trials of Some Newer Disinfectants on Peas

In view of the fact that peas was the only vegetable crop in Manitoba ordinarily receiving seed disinfection and because the acreage of this crop in Manitoba was expanding rapidly, an effort was made to discover which of the newer seed disinfectants applied to peas elsewhere would be most beneficial under Manitoba conditions. Six different disinfectants, some applied at different rates, were tested under field conditions. The results of these trials, tabulated in Table 1, show that in 1943 New Improved Ceresan, Arasan, and U.S.R. 604 significantly improved seed germination in both lots of pea seed used in that year. Spergon, however, increased the stand significantly in only one lot of seed. The yield of harvested seed in 1943

was increased by all disinfectants in one lot of seed but not in the other, although germination in this lot was improved by all but one of the treatments. In 1944 and 1945, none of the seed disinfectants used increased either the percentage of seeds germinating or the yield in any of the seed lots treated.

There appear to be several explanations for these variable results. The increases in germination following treatment in seed lots 1 and 2 (Table 1) indicate that disease (seed-borne or soil-borne) was being controlled. The lack of definite improvement in seed lots 3, 4, and 5 indicated that these lots were relatively healthy or that soil-borne disease was unable to develop. The principal observable difference between the two groups of seed lots was that the first group (lots 1 and 2) consisted of commercial seed, containing a considerable proportion of seeds with cracked seed coats, whereas lots 3 and 4 of the latter group consisted of uninjured hand-threshed seed. Lot 5, although a commercial lot, was apparently uninjured. It has been observed that injury to wheat and flax resulting from mechanical injury to the seed coat tends to impair germination and expose the seed to invasion by soil fungi (15, 16). With peas, other factors also may affect the amount of seedling blight and the degree of control obtained under field conditions by seed disinfection. Soil temperature and moisture (6, 8, 10, 12, 13), time of seeding (1, 18), degree of soil contamination (3, 7, 8, 9, 18), amount of disease in the seed (3, 10, 11), starchiness or wrinkling of seed (12, 19), and lateness of variety (17) are among the factors found to be most important.

Trials with New Improved Ceresan

It has already been mentioned that during the recent world war there was a shortage of seed disinfectants in Canada. Disinfectants (New Improved Ceresan and Half-ounce Leytosan) ordinarily used for treating cereal seed were more plentiful than others used for vegetable seed. An attempt was made, therefore, to adapt the cereal seed disinfectants for use with vegetables. A series of preliminary trials in the greenhouse showed that if either of the named disinfectants was diluted with twice its volume of talc, the resulting dust could be applied with benefit to many kinds of vegetable seeds. This benefit, measured by increases in seed germination and seedling vigour, was obtained even though the seed was sown immediately after treatment. Moreover, heavy doses of the dust failed to cause appreciable injury to the seed.

In the present study, diluted New Improved Ceresan was applied to many kinds of vegetable seed, and an effort was made to determine the effect of the dust on seed germination in different seed lots of the same vegetable variety. Each lot of seed was treated with an excess of the diluted dust, shaken well in a closed container, and the non-adhering dust was screened off. A treated and an untreated lot of seed from each sample was then sown in a bed of unsterilized black loam soil in a greenhouse held at approximately 20° C. In seeding, care was taken to sow in the same seed bed kinds of seed requiring approximately the same time for germination, as differences in rapidity of germination in mixed plantings reduced the rate of testing. Counts of seedlings were generally made one week after the seed began to germinate.

TABLE 2.—EFFECT OF DILUTED NEW IMPROVED CERESAN ON GERMINATION OF DIFFERENT KINDS OF VEGETABLE SEED IN GREENHOUSE SOIL

Plant family	Crop	Percentage increase or decrease in germination
Chenopodiaceae	Beets (garden)	+ 113.1
	Spinach	+ 145.7
	Swiss chard	+ 13.3
Compositae	Lettuce	+ 1.1
Cruciferae	Brussels sprouts	+ 14.1
	Cabbage	+ 16.3
	Cauliflower	+ 11.7
	Kohl rabi	+ 15.5
	Radish	+ 13.8
	Turnips	+ 9.6
Cucurbitaceae	Citron	+ 390.0
	Cucumber	+ 33.8
	Muskmelon	+ 259.0
	Pumpkin	+ 183.6
	Squash	+ 139.4
	Watermelon	+1316.9
Gramineae	Corn (sweet)	+ 18.6
Leguminosae	Beans (garden)	+ 17.8
	Peas (garden)	+ 92.0
	Soybeans	+ 12.8
Liliaceae	Leeks	+ 5.1
	Onions	+ 6.1
Solanaceae	Peppers	+ 34.6
	Tomatoes	+ 14.6
Umbelliferae	Carrots	+ 15.5
	Celery	− 7.2
	Parsnip	− 8.2

After the data obtained from these tests were assembled, it was found that some kinds of vegetables benefited much more than others from the seed treatment employed. As is shown in Table 2, the seed of crops belonging to the families *Cucurbitaceae*, *Chenopodiaceae*, and *Leguminosae* germinated much better after treatment than did that of the *Liliaceae* and *Cruciferae*. There was, however, some variation in the response to treatment among different vegetables within individual families. In the *Cucurbitaceae*, most of the vegetables except cucumbers benefited appreciably. In the *Umbelliferae*, seed of carrots and parsnips appeared to be slightly injured by the treatment, in that the percentage germination of the treated seed was slightly less than that of the untreated.

A further examination of the greenhouse germination data showed that there was no consistent varietal difference in the response to seed treatment. As the representative data in Table 3 indicate, there was often

TABLE 3.—VARIATION IN GERMINATION (PERCENTAGE INCREASE OR DECREASE) AMONG SAMPLES OF VEGETABLE SEED TREATED WITH DILUTE NEW IMPROVED CERESAN AND PLANTED IN NON-STERILE SOIL IN THE GREENHOUSE

Crop	Variety	Seed sample		
		1	2	3
Beans	Brittle Wax	+ 92	+ 23	+ 3
	Navy	+ 6	0	+ 66
	Pencil Pod Black Wax	+ 2	+ 8	+ 9
Beet (table)	Early Wonder	+ 98	+ 100	—
	Good for All	+ 157	+ 142	—
	Ohio Canner	+ 71	+ 134	—
Cabbage	Copenhagen Market	+ 11	+ 46	+ 15
	Golden Acre	+ 42	+ 82	+ 10
	Penn State Ballhead	0	+ 7	− 16
Carrot	Danvers Half-long	+ 26	+ 15	+ 3
	Oxheart	+ 6	0	+ 47
Cauliflower	Dry Weather	+ 10	+ 68	—
	Early Snowball	− 3	− 11	+ 55
Corn (sweet)	Early Golden Sweet	+ 26	+ 15	—
	Golden Bantam	+ 4	+ 13	+ 27
Cucumber	Ace	+ 90	0	+ 8
	Chicago Pickling	+ 37	+ 53	− 3
	Delcrow	+ 570	+ 238	+ 178
Lettuce	Grand Rapids	+ 7	− 2	− 63
	New York Special No. 12	+ 50	− 18	+ 2
Muskmelon	Bender's Surprise	+ 902	+ 145	—
	Edible Gold	+1400	+ 200	—
	Extra Early Knight	+ 718	+ 57	—
Onion	Large Red Wethersfield	+ 9	+ 23	+ 3
	White Portugal	0	+ 11	+ 8
	Yellow Globe Danvers	0	+ 1	− 13
Peas	Alderman	+ 70	+7800	—
	American Wonder	+ 8	+ 60	+ 155
Spinach	Bloomsdale	+ 150	+ 177	+1183
	King of Denmark	+ 102	+ 26	+ 350

a greater difference in the response between two samples of seed of the same variety than between two samples of different varieties.

From observations on seed germination, it would appear that dusting the seed with diluted New Improved Ceresan is of value with beets, citron, cucumbers, muskmelon, peas, peppers, pumpkin, spinach, squash, and watermelon. Observations on seedling growth in the greenhouse and field showed, too, that with beans and sweet corn, the treatment, while not always improving germination, tended to increase the vigour of the seedlings. The latter two crops should, therefore, be added to the list of those benefiting from this treatment.

TABLE 4.—PERCENTAGE INCREASE OR DECREASE IN GERMINATION OF BEAN, SWEET CORN, AND PEA SEED OF THREE DIFFERENT AGES FOLLOWING TREATMENT WITH DILUTED NEW IMPROVED CERASAN

Variety number	Beans			Corn			Peas		
	1944	1945	1946	1944	1945	1946	1944	1945	1946
1	1	27	7	−9	22	222	18	25	29
2	− 8	70	9	16	248	772	68	77	675
3	− 5	0	21	15	31	17	30	132	122
4	9	16	81	24	250	278	11	67	28
5	58	101	21	7	193	540	5	45	87
6	−15	1233	25	10	115	192	45	173	131
7	14	70	62	23	72	280	9	−4	32
8	12	14	44	18	183	130	80	285	105
9	0	100	50	8	155	161	44	36	157
10	4	7	30	7	24	324	49	247	200
11	40	62	47	11	272	291	5	63	86
12	23	91	19	13	91	193	42	76	63
13	9	635	75	14	132	412	169	582	200
14	− 9	2	29	29	131	367	24	60	89
15	13	3	50	23	222	423	14	134	115
16	14	24	32	10	94	200	43	227	174
17	1	64	12	−5	88	152	47	126	118
18	23	28	50	4	157	344	46	44	69
19	16	−4	59	21	163	1500	23	0	114
20	− 1	205	13	7	67	135	−3	0	176
21	14	55	33	4	178	224	65	194	634
22	32	10	42	20	37	114	21	85	110
23	0	41	15	23	59	285	13	140	218
24	8	56	56	53	310	1133	47	104	167
25	20	27	52	45	372	2400	103	247	50
26	—	—	—	7	189	240	13	27	23
27	—	—	—	0	72	230	16	2300	14
28	—	—	—	14	513	350	—	—	—
Mean	8.3	45.6	35.5	12.2	118.7	239.6	29.4	76.8	99.4

Effect of Age of Bean, Pea, and Sweet Corn Seed on Its Germination following Treatment with Diluted New Improved Ceresan

In the spring of 1944, one-pound lots of a number of bean, pea, and sweet corn varieties were purchased from several Canadian seed houses. At planting time, a portion of each lot was treated with diluted New Improved Ceresan by the method described earlier in this paper. This treated seed was then sown in the field in a row adjacent to another row sown with untreated seed of the same variety. The remainder of the untreated seed of each lot was placed in dry, aired storage, at ordinary room temperature. In 1945 and 1946, other portions of the stored seed were treated in the same manner and sown along with untreated portions. Each year, one month after seeding, the seedlings in the individual rows were counted and the percentage increase or decrease in germination resulting from seed treatment was calculated. The data obtained in this way (Table 4) show that, with peas and sweet corn, there was a distinct tendency for aged seed to benefit more than fresh seed from the disinfection employed. With beans, the data obtained were inconclusive.

In all the three vegetables tested, the germinability of both the treated and the untreated seed tended to decrease as the seed became older. A similar decrease in germinability has been found by other workers (4, 5, 14)

in field corn. In the present investigation, with peas and sweet corn at least, it was found that the rate of decrease was reduced if the seed was treated. In other words, as the seed became older, seed treatment apparently increased the proportion of seeds able to develop into growing plants. The observations of Dunegan and Koehler (5), that seed vitality in field corn tends to decrease with ageing in spite of the fact that seed-borne pathogenic fungi die out while the seed is held in storage, may have some bearing on the present finding. Devitalized, aged seed may, therefore, benefit considerably more than fresh seed from the protection against soil fungi afforded by a suitable treatment.

Varietal Resistance of Beans, Peas, and Sweet Corn to Some Common Diseases in the Field

In Manitoba, losses from disease in beans, peas, and sweet corn have not been hitherto generally severe. In beans, injurious outbreaks of bacterial halo blight (*Pseudomonas medicaginis* Sackett var. *phaseolicola* (Burkh.) Stapp and Kotte) have been frequently encountered in small, garden plantings but very seldom in large plantings. In peas, powdery mildew (*Erysiphe Polygoni* DC.) has been the disease most commonly observed in Manitoba. Various root rots and leaf spots of peas have been observed in relatively small amounts, while severe attacks by bacterial blight (*Pseudomonas Pisi* Sackett) have occurred but rarely. In sweet corn, the principal disease observed thus far in Manitoba has been smut (*Ustilago Maydis* (DC.) Cda.) but it has been confined chiefly to the very early varieties Dorinny and Gill's Early Market.

A number of workers have investigated varietal resistance to disease in these crops. In most cases, the varieties tested by these workers were different from the varieties offered for sale in Canada, and the results published were not altogether applicable in Manitoba.

In view of the possibility that the shortage of vegetable seeds in Canada would encourage distribution of varieties susceptible to disease, it seemed desirable to determine which of the varieties offered in the catalogues of Canadian seed houses were likely to be resistant to disease under Manitoba conditions. A number of widely advertised varieties of beans, peas, and sweet corn were selected for testing, and the seed was sown at Winnipeg each year over a 3-year period on summerfallow land. During each summer, the plants were periodically examined for diseases and the amount of each kind was noted. With one exception (beans, 1945) no attempt was made to increase the amount of disease by artificial means, as ordinarily natural seed-borne and soil-borne inoculum appeared to be present in sufficient amounts.

In beans, stem girdling induced by *Pellicularia filamentosa* (Pat.) Rogers (= *Rhizoctonia Solani* Kühn) developed abundantly during the spring of 1944, almost destroying the stand in some varieties but causing very little injury to others. The varieties Navy and Great Northern were conspicuously resistant. This disease did not appear in 1945 and 1946. Bacterial halo blight varied considerably in amount, but usually the least disease occurred on the varieties Dwarf Horticultural, Flageolet, Kentucky Wonder Pole, Medal Refugee, Stringless Green Refugee, and White

Marrowfat. Anthracnose (*Colletotrichum Lindemuthianum* (Sacc. and Magn.) Bri. and Cav.) appeared to a slight extent in 1945 in the varieties Improved Golden Wax, and Navy.

In the test with peas at Winnipeg, only four diseases were severe enough to warrant recording. Bacterial blight (*Pseudomonas Pisi* Sackett), leaf and pod spot (*Ascochyta Pisi* Lib.), and leaf blotch (*Septoria Pisi* Went.) were observed in each year of the 3-year test but there was no clear indication that certain varieties were consistently more resistant than others. Powdery mildew (*Erysiphe Polygoni* DC.) was not observed in 1944 but was abundant in 1945 and 1946. The pea varieties showing the least disease over the 3-year period of testing were Dwarf Alderman, Dwarf Grey Sugar, Everbearing, Improved Stratagem, Onward, and Radium. The variety Onward appeared to be particularly resistant.

Only two diseases, neither of them severe, were observed during the trials with corn. These diseases were smut (*Ustilago Maydis* DC.) and rust (*Puccinia Sorghi* Schw.). Smut occurred to some extent in almost every variety in 1944 but in only a few during 1945 and 1946. On the whole, Dorinny was the only variety in the corn trials that appeared to be distinctly susceptible to this disease. Rust was comparatively abundant in 1944 but was little in evidence during 1945 and 1946. According to the observations on rust made in 1944, Early Golden Market, Early Golden Sweet, Marcross 13.6, McFayden's D-2 Hybrid, and Yellow Marvel were the most susceptible varieties.

SUMMARY

Treatment of pea seed with various seed disinfectants gave variable results. In some years, treatment increased both germination and yield, while in others it did not. Occasionally, even a substantial improvement in germination was not followed by an improvement in yield.

New Improved Ceresan or Half-ounce Leytosan, diluted to three times the original volume with talc, was found to be safe for application in excess to a wide variety of vegetable seeds. There appeared to be no need for an exact measurement of the quantity of diluted dust to be applied to a given amount of seed. Treated seed of cucurbits, peas, beets, spinach, and peppers showed greatly improved germination over untreated seed when sown in unsterilized soil. The benefit to other kinds of seed was less, while with celery and parsnip there apparently was none at all.

Old seed of peas and sweet corn appeared to be benefited more than fresh seed by treatment with diluted New Improved Ceresan.

Varietal resistance of beans, peas, and sweet corn to disease could not be determined accurately under field conditions during a 3-year trial. The variation in amount of disease in different varieties from year to year was too great to allow definite conclusions regarding their susceptibility to the diseases observed.

REFERENCES

1. Brett, C. C., W. A. R. Dillon Weston and J. R. Booer. Seed disinfection III. Experiments on the germination of peas. Seed protection by the use of disinfectant dusts containing mercury. J. Agr. Sci. 27 : 53-66. 1937.
2. Cunningham, H. S. Vegetable seed treatment tests in New York. Pl. Dis. Reptr. 23 : 380-381. 1939.
3. Davis, G. N. Germination of treated and untreated pea seeds in autoclaved and unautoclaved soil. Proc. Assoc. Off. Seed Analysts N. Amer. (1937) : 121-125. 1938.
4. Dunegan, G. H. Influence of age on the value of seed corn. Trans. Ill. State Acad. Sci. 33 : 28-29. 1940.
5. Dunegan, G. H., and B. Koehler. Age of seed corn in relation to seed infection and yielding capacity. J. Amer. Soc. Agron. 36 : 436-443. 1944.
6. Forsberg, J. L., E. Olson and A. M. Binkley. Experiments with pea seed treatments in Colorado. Phytopath. 24 : 753-759. 1944.
7. Haenseler, C. M. Effect of organic mercury seed treatment on germination and yield of peas. 48th Ann. Rept. New Jersey Agr. Exp. Sta. (1927) : 232-238. 1928.
8. Hutton, E. M. Field emergence and yield of garden peas as affected by treatment of the seed with fungicidal dusts. J. Coun. Sci. Industr. Res. Aust. 17 : 71-74. 1944.
9. Hyde, E. O. C. Observations on the germination and seedling establishment of peas. N.Z. J. Sci. Tech. A. 21 : 61-70. 1939.
10. Hynes, H. J. Defective germination in peas. Agr. Gaz. N.S.W. 38 : 251-254. 1927.
11. Hynes, H. J. and R. D. Wilson. Fungicidal treatment of pea seed. Beneficial results from dusting. Agr. Gaz. N.S.W. 50 : 657-659. 1939.
12. Jones, L. K. Factors influencing the effectiveness of organic mercury dusts in pea seed treatment. J. Agr. Res. 42 : 25-33. 1931.
13. Jordan, E. Zur Gemüsesamenbeizung. Obst-und Gemüsebau 80 : 54-55. 1934.
14. Kiesselbach, T. A. Effect of age, size, and source of seed on the corn crop. Nebraska Agr. Exp. Sta. Bull. 305. 1937.
15. Machacek, J. E., and F. J. Greaney. Studies on the control of root-rot diseases of cereals. IV. Influence of mechanical seed injury on infection by *Fusarium culmorum* in wheat. Can. J. Res. C, 14 : 438-444. 1936.
16. Machacek, J. E., and A. M. Brown. Threshing-injury to flax seed in Canada. Sci. Agr. 25 : 601-625. 1945.
17. McNew, G. L. Effect of seed treatment and the stand and yield of peas. Canner 92 (6) : 56, 58, 60, 62; 92 (7) : 16, 18, 20. 1941.
18. Ogilvie, L., H. E. Croxall and C. J. Hickman. Cuprous oxide as a seed protectant for peas. Rept. Agr. Hort. Res. Sta. Bristol (1939) : 88-89. 1940.
19. Walker, J. C., E. J. Delwiche and P. G. Smith. Pea seed treatment with chemical dusts. J. Agr. Res. 41 : 143-147. 1940.

THE REACTION OF RESCUE WHEAT TO SAWFLY DAMAGE[1]

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INTRODUCTION

Rescue is a solid-stemmed, hard red spring wheat developed in a co-operative breeding program for resistance to attack by the wheat stem sawfly (*Cephus cinctus* Nort.). It is the result of a cross between Apex and S-615. Apex is very susceptible to sawfly attack, whereas S-615 is normally resistant. The hybrid line, from which Rescue resulted, was selected in 1942. From 1943 to 1947 it was tested at five stations in Saskatchewan and Alberta, and from 1945 to 1947, in similar trials in Montana. Additional information as to sawfly reaction was obtained from a series of varietal test plots grown at various points in south western Saskatchewan in 1946 and 1947. Rescue was grown on a field scale in 1946, and some general observations on field behaviour to sawfly attack were obtained. This paper summarizes the results.

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Figure 1. Sawfly damage on wheat varieties. Left to right, Rescue selections, Thatcher, and Rescue. (*Photograph by Kloppenborg*).

TABLE 1.—PER CENT CUTTING BY SAWFLIES IN WHEAT VARIETIES IN NURSERY TRIALS IN SASKATCHEWAN AND ALBERTA, 1943-1947

Station	Year	Per cent cut			
		Rescue	Thatcher	S-615	Apex
Nobleford	1943	1.6	51.6	1.3	46.6
	1944	0.8	18.2	4.0	29.0
	1945	1.0	67.0	2.4	60.6
	1947	4.0	79.0	6.0	88.0
	Average	1.8	54.0	3.4	56.0
Scott	1943	9.6	59.2	13.5	73.1
	1944	2.4	19.3	2.6	27.4
	1945	0.6	52.4	2.4	80.4
	1946	2.5	40.1	4.8	60.8
	1947	3.1	42.7	3.8	70.0
	Average	3.6	42.7	5.4	62.3
Shaunavon	1943	8.2	79.2	12.5	87.2
	1944	2.6	57.2	3.1	75.4
	1945	3.8	87.4	2.6	90.8
	1946	6.0	48.7	9.6	42.5
	Average	5.2	68.1	7.0	74.0
Swift Current	1943	3.6	63.6	7.6	75.2
	1944	2.8	80.3	6.5	88.6
	1945	1.0	80.0	1.0	86.0
	1946	2.0	47.4	2.1	43.2
	1947	4.0	44.4	5.0	86.0
	Average	2.7	63.1	4.4	75.8
Regina	1943	15.2	92.2	18.1	91.2
	1945	43.6	92.6	73.0	95.2
	1946	19.5	75.2	24.8	80.8
	1947	67.0	84.3	72.0	94.0
	Average	36.3	86.1	47.0	90.3
Average		9.3	61.9	12.7	71.4

NURSERY TRIALS IN ALBERTA AND SASKATCHEWAN

Rescue and other varieties were grown in sawfly nurseries at Nobleford, Alberta, and at Scott, Swift Current, Shaunavon, and Regina in Saskatchewan, over the period 1943-1947. The methods used in conducting these nurseries have been described in detail (1). Briefly, the varieties were grown in single, ten foot rows, one foot apart and replicated five times at each station during the first three years, and four times during the last two. The nurseries were seeded early and only one date of planting was used. They were exposed to a heavy natural infestation of sawflies. The criterion of damage used was the average of two independent estimates of the percentage of stems cut by the sawflies.

A summary of the results obtained with Rescue, the parental varieties, and Thatcher, is presented in Table 1. The results show that Rescue exhibited a high degree of resistance at all stations except Regina. In none of the four years did it show high resistance there, and, in 1947 the damage was extremely heavy. However, it still showed much less damage than Apex or Thatcher. Rescue tended to be more resistant than the

TABLE 2.—PER CENT CUTTING BY SAWFLIES IN WHEAT VARIETIES IN VARIETAL TEST PLOTS IN SOUTH WESTERN SASKATCHEWAN, 1946-1947

Station	Year	Per cent cut	
		Rescue	Thatcher
Cabri	1947	1.0	1.5
Canuck	1946	0.2	16.2
	1947	0.5	31.2
Carmichael	1946	2.2	38.8
	1947	1.5	67.5
Fox Valley	1946	0.0	3.0
	1947	1.0	60.0
Gravelbourg	1947	0.2	8.0
Kyle	1946	1.5	16.2
	1947	2.8	22.5
Kincaid	1946	1.2	72.5
Limerick	1947	20.0	50.0
McMahon	1947	2.8	20.0
Riverhurst	1946	1.0	6.8
	1947	0.8	8.8
Shackleton	1946	2.2	92.8
Shaunavon	1946	3.0	33.8
	1947	2.0	86.2
Tugaske	1946	3.5	31.2
	1947	1.5	45.0
Valjean	1946	2.5	5.8
	1947	2.0	62.5
Average		2.4	35.5

resistant parent, S-615, for all years at all stations. The differences were not statistically significant, however, except at Regina in 1945. The appearance of Rescue and susceptible types in the Nobleford nursery is shown in Figure 1.

In addition to the above results, information on the sawfly reaction of Rescue was obtained from a series of varietal tests conducted at various points in south-western Saskatchewan. In all, 22 tests were conducted during 1946 and 1947. These were standard yield trials, in which the varieties were grown in three rod row plots, quadruplicated. At maturity, the amount of sawfly damage in each plot was estimated. A summary of the results obtained is presented in Table 2. Rescue exhibited a high degree of resistance in all tests except one. The resistance was only fair at Limerick in 1947.

NURSERY TRIALS IN MONTANA

The nursery trials in Montana were conducted in essentially the same manner as those outlined above. The only differences were that three replicates were used, instead of four or five, and generally more than a single planting date was used. A summary of the results obtained is presented in Table 3. Rescue exhibited satisfactory resistance in most of the 1945 and 1946 tests. At the No. 1 test in Teton county, and in the test at Valley county, the resistance was only fair. In 1947, the general level of resistance of Rescue was much lower, and in a number of tests, it was not appreciably better than that of Thatcher.

Results of further tests were supplied by Dr. R. H. Bamberg, Agronomist, Bureau of Plant Industry, U.S.D.A. In 1947, he grew Rescue, Thatcher, Ceres, and several selections of Rescue at Plentywood in Sheridan county, Montana. There were no differences between Rescue or the Rescue selections, and the susceptible varieties, Thatcher and Ceres. All were cut about forty-five per cent.

FIELD OBSERVATIONS

Observations in Alberta

A number of fields of Rescue were grown in 1946. When the crop was mature, the fields were examined, and the amount of sawfly damage noted. Similar notes were taken on comparable fields of susceptible varieties. A summary of the results obtained is presented in Table 4. Rescue was highly resistant in all fields.

TABLE 3.—PER CENT CUTTING BY SAWFLIES IN WHEAT VARIETIES IN NURSERY TRIALS IN MONTANA, 1945-1947

County	Per cent cut					
	1945[1]		1946[2]		1947	
	Rescue	Thatcher	Rescue	Thatcher	Rescue	Thatcher
Blaine	1	28	—	—	1[3]	18[3]
Daniels (1)	1	20	—	—	30[5]	50[5]
Daniels (2)	—	—	—	—	33	77
Daniels (3)	—	—	—	—	50	56
Dawson	—	—	—	—	6[4]	22[4]
Fergus	—	—	—	—	18[5]	63[5]
Glacier (1)	—	—	2	57	18	64
Glacier (2)	—	—	4	68	—	—
Pondera	9	72	—	—	—	—
Richland	—	—	—	—	T	7
Roosevelt	2	83	—	—	—	—
Sheridan (1)	4	70	—	—	6	18
Sheridan (2)	—	—	—	—	31	39
Sheridan (3)	—	—	—	—	23[5]	59[5]
Teton (1)	17	58	15	81	6	36
Teton (2)	4	67	T	35	T	3
Valley	17	85	—	—	—	—
Average	7	60	5	60	17	39

[1] One planting date only between April 24 and May 5.
[2] Average of three planting dates between April 19 and May 10.
[3] One planting date only.
[4] Average of two planting dates, April 29 and May 9.
[5] Average of four planting dates between April 24 and May 28.
All other 1947 nurseries average of three planting dates between April 24 and May 28.

In 1947 ten fields of Rescue in various districts were examined and no appreciable damage observed. No reports of any serious damage to Rescue were received from growers.

The appearance of typical fields of Rescue and Thatcher is shown in Figure 2.

Observations in Saskatchewan

A series of observations, similar to those described above were made in Saskatchewan in 1946. A summary of the results is presented in Table 5. They are essentially similar to those obtained in Alberta. The field observations in both provinces agree closely with the results of nursery trials. However, no field observations have been made in the Regina area, since Rescue is not grown there.

Observations in Montana

The observations on field plantings of Rescue in 1946 and 1947 may be summarized as follows:

In 1946, data were obtained from commercial plantings in strips separated by fallow. A summary is presented in Table 6.

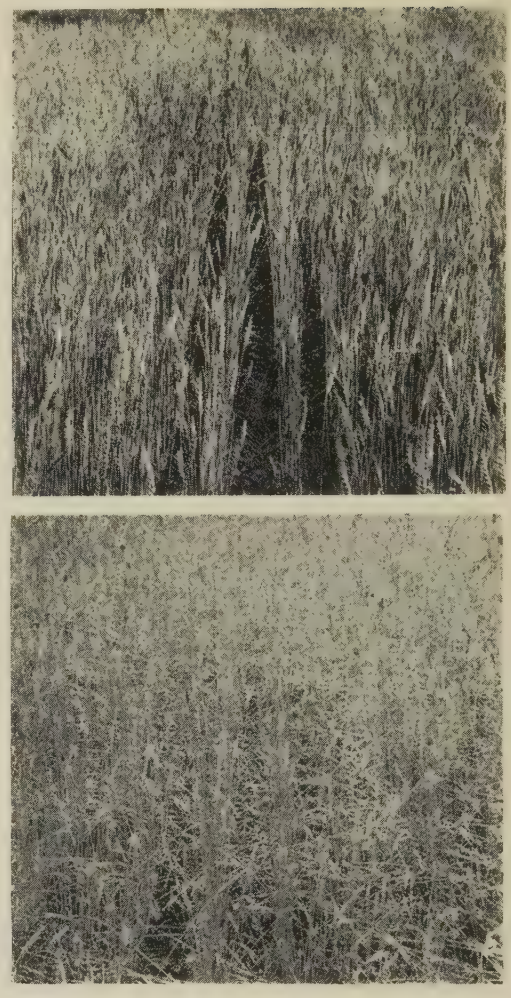

FIGURE 2. Rescue (top) and Thatcher (bottom) fields at Nobleford, showing differences in sawfly damage. (*Photographs by Kloppenborg*).

A summary of data from four localities in Teton county in 1947 is presented in Table 7. The data given are estimated minimum, maximum, and average losses. In the same year, miscellaneous observations in Sheridan, Daniels, Glacier, Toole, Pondera, and Teton counties, where an estimated fifty or more commercial fields were examined, showed sawfly damage in susceptible varieties varying from 5 to 95 per cent, with from 25 to 40 per cent being the average loss. In adjacent fields of Rescue, from 0 to 10 per cent damage occurred in the first rod, but in no instance did a field average loss exceed 3 to 5 per cent.

These observations show that the sawfly resistance of Rescue in Montana fields is very satisfactory. This is in contrast with results from nursery trials in the same areas, where in several instances, Rescue failed to show appreciable resistance.

TABLE 4.—PER CENT CUTTING BY SAWFLIES IN FIELDS OF WHEAT IN ALBERTA, 1946

Station	Per cent cut	
	Rescue	Check[1]
Milk River	8.0	27
Carmangay	0.5	9
Craddock	0.5	32
Brant	4.0	9
Milo	2.0	54
Vulcan	3.0	34
Mossleigh	2.0	12
Bindloss	1.0	14
Average	3.0	24

[1] Thatcher, Marquis or Red Bobs.

TABLE 5.—PER CENT CUTTING BY SAWFLIES IN FIELDS OF WHEAT IN SASKATCHEWAN, 1946

Station	Per cent cut	
	Rescue	Check[1]
Carmichael	7.0	70
Shaunavon	3.0	9
Gravelbourg	3.0	32
Wymark	1.0	26
Pambrun	1.0	20
Limerick	2.0	33
Radville	7.0	83
Hazlet	0.5	8
Cabri	2.0	57
Shackleton	1.0	21
Eston	0.5	17
Sceptre	0.5	8
Laporte	0.5	21
Richlea	0.5	16
Average	2.0	30

[1] Thatcher, Marquis or Apex.

TABLE 6.—PER CENT CUTTING BY SAWFLIES IN FIELDS OF WHEAT IN MONTANA, 1946

Location	Variety	Per cent cut
Teton county—Wuest	Thatcher	54
	Rescue	3
	Winter wheat	29
Teton county—Stenson	Thatcher	23
	Rescue	Tr.
Teton county—Imbody	Winter wheat	18
	Rescue	1

TABLE 7.—MINIMUM, MAXIMUM, AND AVERAGE PER CENT CUTTING, IN FIELDS OF WHEAT IN TETON COUNTY, MONTANA, 1947

Locality	Variety	No. sample strips	Per cent cut		
			Min.	Max.	Av.
E. of Choteau	Thatcher and Ceres	4	30	90	37
	Rescue	2	0	3	1
N. of Choteau	Ceres	6	T	85	35
	Thatcher	3	5	90	30
	Rescue	1	0	5	2
NE. of Farmington	Ceres	12	10	80	40
	Winter wheat	2	25	80	35
	Rescue	19	0	5	2
E. of Agawan	Thatcher	4	30	90	50
	Rescue	2	0	5	3

DISCUSSION

Rescue wheat has shown a high degree of sawfly resistance in both nursery trials and field plantings over wide areas in Alberta and Saskatchewan. At only one point, Regina, has resistance not been satisfactory. How large an area this station represents is not known at the present time. It seems unlikely that it represents more than a relatively small part of the total acreage menaced by sawflies in these provinces.

In Montana, the status of Rescue is not so clear. It has shown satisfactory resistance in all fields that have been observed, and in most nursery trials in 1945 and 1946. However, it was relatively susceptible in many nursery trials in 1947.

The reasons for the variations in reaction to damage are not known. It would be idle to speculate on these until more experimental data are available. It is probable that they involve one, or a combination of the following: inherent differences in the sawfly populations; environmental effects on the expression of the solid-stem character; variations in the nutrition of the plant, which in turn, might affect the nutrition of the insect; or faulty technique in conducting nursery trials. These possibilities are under investigation at the present time.

SUMMARY

The reaction of the new solid-stemmed, hard red spring wheat, Rescue, to damage by the wheat stem sawfly (*Cephus cinctus* Nort.) was studied. In nursery trials in Alberta and Saskatchewan, during the period 1943-1947, Rescue showed a high degree of resistance at four stations. At the fifth station, resistance was not high in any year, and in one year, Rescue was almost completely susceptible. In 22 yield tests conducted in south-western Saskatchewan in 1946-1947, the resistance of Rescue was satisfactory. Field observations in Alberta and Saskatchewan were in agreement with the results from the nursery trials. Nursery trials were conducted at eight stations in Montana in 1945, four in 1946, and thirteen in 1947.

In 1945, at six of the stations, the resistance of Rescue was good, and at the other two, it was fair. At three stations in 1946, resistance was good, and at the other fair. Resistance was good at six stations in 1947, fair at two, and unsatisfactory at five. In contrast to the nursery trial results, all the field plantings of Rescue examined in 1946-1947 showed high resistance. The reasons for fluctuations in damage are not known.

REFERENCE

1. Platt, A. W., and C. W. Farstad. The reaction of wheat varieties to wheat stem sawfly attack. Sci. Agr. 26 : 231-247. 1946.

THIAMINE AND RIBOFLAVIN IN GROWING FORAGE CROPS[1]

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There is comparatively little information available on the B-vitamin contents of growing forage crops. This is probably because they are not regarded as necessary sources of the vitamins in question for animals consuming them. It has been demonstrated (4) that some vitamins of the B-complex are synthesised by the intestinal microflora of some grazing animals. However, the concentration of vitamins in growing plants is of general interest, and is of importance in the nutrition of animals which consume these plants and which are not able to synthesise these vitamins. Since forage crops were available on the University plots it was decided to ascertain their thiamine and riboflavin contents as they would be consumed by animals in the pasture. The plants were grasses and legumes commonly grown in Manitoba for pasture purposes.

Booth (3) has reported the average thiamine and riboflavin contents of a number of grasses grown in Great Britain to be 1.1 and 1.3 μg/g, respectively. These were seasonal averages for fresh undried grasses. Most of the other data in the literature are for dried material.

Vail, Tobiska and Douglass (8) tested alfalfa dried in various ways for vitamin B_1. They expressed the vitamin content in units per gram, a unit being defined as the amount of vitamin which, fed daily to rats, gave a weekly gain in weight of 3 to 4 g. This corresponds approximately to a Chase-Sherman unit, or 1.5 μg of thiamine. The values for three cuttings, each dried in three different ways, ranged from 1.5 to 5.1 μg/g. No one drying method gave consistently higher or lower values. Four different varieties, all dried in diffused light, showed little variation and averaged 2.6 μg/g. Storage caused a reduction in vitamin B_1 content. This was especially marked in the weathered surfaces and in the centres of stacks. Vitamin G (B_2) was present in amounts ranging from 4.5 to 7.5 μg/g and was unaffected by differences in drying methods or variety.

Hunt, Record and Bethke (7) studied the influence of maturity on vitamins B_1 and G in alfalfa, clover and timothy. Their samples were dried after cutting and before assay. They found that the vitamin G content was greater than the B_1 content, both decreasing as the crop

[1] Contribution from the Dept. of Chemistry, The University of Manitoba, Winnipeg, Man. Published as Paper No. 1 of the Nutritional Research Institute of the University of Manitoba.

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TABLE 1.—VITAMIN B_1 AND G CONTENTS OF HAYS. μg/g
(Hunt *et al.*, 7)

	B_1	G
Alfalfa	2.4–3.8	9.9–19.5
Timothy	0.8–1.7	3.8– 9.9
Clover	2.6–2.9	12.0–15.0

TABLE 2.—THIAMINE AND RIBOFLAVIN CONTENTS OF GRASSES

(Dry basis)

		Sampling date						Average
		June 3	June 12	June 18	June 25	July 2	July 9	
Brome	Moisture %	68.5	76.3	72.1*	73.7	66.0	51.2	
	Thiamine μg/g	2.5	2.5	3.6	4.6	3.2	2.7	3.2
	Riboflavin μg/g	9.2	7.2	4.3	9.1	9.4	6.1	7.6
Slender wheat	Moisture %	63.7	68.5	66.8*	75.9	57.3	41.2	
	Thiamine μg/g	4.1	2.9	4.2	6.6	2.8	2.9	3.9
	Riboflavin μg/g	10.2	10.2	7.2	13.3	6.8	5.1	8.8
Crested wheat	Moisture %	64.5	68.5	58.8*	64.3	61.2	51.0	
	Thiamine μg/g	3.1	2.5	2.9	3.9	3.6	4.1	3.5
	Riboflavin μg/g	11.5	8.9	6.3	12.3	8.0	7.1	9.0
Timothy	Moisture %	68.4	75.5	76.1*	78.5	68.8	55.7	
	Thiamine μg/g	1.9	2.9	2.5	4.2	2.9	2.3	2.8
	Riboflavin μg/g	13.6	17.6	5.0	10.2	7.4	6.8	10.1
Meadow fescue	Moisture %	70.3	75.1	74.5†	65.4*	72.3	62.0	
	Thiamine μg/g	8.4	6.0	5.1	21.1	21.7	9.2	11.9
	Riboflavin μg/g	15.5	9.2	7.1	4.9	8.7	6.1	8.6

* Headed since previous analysis.
† Partly headed since previous analysis.

matured. The ranges of values obtained for several samples at varying degrees of maturity are given in Table 1. The units used to express vitamin content were the same as those used by Vail *et al.* (8) and are converted to μg/g in the table. In general increased maturity resulted in lower values. Sunshine was found to have no destructive effect on the vitamin G content of hay, but 0.68 inches of rain lowered it 50 per cent. Bluegrass, wheat and rye grasses compared favourably in vitamin content with alfalfa and clover.

Heiman, Carver and Cook (5) confirmed the conclusion that the more mature plant has less vitamin G than the immature one. Their results were reported in terms of the vitamin content of skim milk, so are difficult to convert to absolute units.

EXPERIMENTAL AND DISCUSSION

The grasses examined were brome grass, slender wheat, crested wheat, timothy and meadow fescue. The legumes were alfalfa, red clover and alsike. These were seeded in the spring of 1946. They were sampled at approximately weekly intervals during the spring and early summer of 1947 until they had begun to seed. Usually these crops are cut for hay or by grazing before they have matured this much.

The upper parts of the plants were cut for analysis, representing the part usually consumed by grazing animals. Moisture was determined by the vacuum oven method. Thiamine was determined by the method of Hennessy (6) and riboflavin by that of Andrews (1, 2). The experimental data for the grasses are given in Table 2 and those for the legumes in Table 3.

TABLE 3.—THIAMINE AND RIBOFLAVIN CONTENTS OF LEGUMES

(Dry basis)

		Sampling date						Average
		June 2	June 11	June 17	June 26	July 3	July 7	
Alfalfa	Moisture %	75.0	79.0	79.5	78.4	76.7*	72.2	
	Thiamine μg/g	7.2	8.1	8.3	7.4	6.9	6.8	7.5
	Riboflavin μg/g	18.0	15.7	20.5	14.4	14.6	11.9	15.9
Red clover	Moisture %	76.2	81.3	83.7	81.8	84.7	81.6*	
	Thiamine μg/g	7.6	5.9	9.2	7.2	5.2	3.8	6.5
	Riboflavin μg/g	25.2	17.1	16.6	25.3	20.9	9.2	19.1
Alsike	Moisture %	76.9	81.4	82.8	81.8	81.8*	87.8	
	Thiamine μg/g	8.7	10.2	9.9	9.3	8.8	6.6	8.9
	Riboflavin μg/g	24.2	19.9	16.9	23.1	12.6	21.3	19.7

* Flowered since previous analysis.

The results of the vitamin assays are reported on a "dry matter" basis. In this presentation the name thiamine is used in preference to vitamin B or B_1, and riboflavin rather than vitamin B_2 or G.

There is considerable variation in the thiamine content of the grasses. Timothy shows the lowest values, and meadow fescue the highest, while slender wheat, crested wheat and brome contain somewhat more of the vitamin than does timothy. Slender wheat, crested wheat and timothy are slightly better sources of riboflavin than brome or meadow fescue. The averages for both of these nutrients are higher than those reported by Booth (3). Generally, the riboflavin content of the grasses decreases during the early part of the growing season, increases just after heading, then decreases again till seeding. Thiamine contents do not show any such uniform trends, though the highest values occur after heading. Meadow fescue contains more thiamine than riboflavin. The other grasses studied are better sources of riboflavin than of thiamine.

The legumes, too, are better sources of riboflavin than of thiamine. Alsike contains more of either vitamin than does alfalfa or red clover. Red clover is a better source of riboflavin than alfalfa while the latter is a slightly better source of thiamine than the former. With the possible exception of riboflavin in alsike, the legumes showed an initial increase, then a gradual drop in both thiamine and riboflavin content throughout the growing season. This is in harmony with the observations of Hunt *et al.* (7) and of Heiman and his co-workers (5). The legumes are better sources of both vitamins than any of the grasses assayed, except meadow fescue. The latter contains more thiamine than any of the legumes studied. Its riboflavin content, however, is not as high.

It is appreciated that these data represent values for single plots and may not be average. They do suggest that the thiamine and riboflavin contents of forage crops are large enough to supply considerable amounts of these vitamins to grazing animals.

SUMMARY

Most forage crops contain more riboflavin than thiamine. An exception is meadow fescue. The legumes are better sources of both vitamins than the grasses, except that meadow fescue contains more thiamine than any of the legumes studied.

The riboflavin content of the grasses decreases during the early part of the growing season, increases just after heading, then decreases again till seeding. The highest thiamine contents of the grasses occur after heading.

The thiamine and riboflavin contents of the legumes show an initial increase, then decrease gradually until the plants begin to seed.

ACKNOWLEDGMENTS

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REFERENCES

1. Andrews, John S. A collaborative study of riboflavin assay methods. Cereal Chem. 20 : 3-23. 1943.
2. Andrews, John S. Report of the 1942-43 Methods of Analysis Subcommittee on Riboflavin Assay. Cereal Chem. 20 : 613-25. 1943.
3. Booth, Vernon. Vitamins in grass. Chem. and Ind. 61 : 255-6. 1942.
4. Burkholder, P. R., and Ilda McVeigh. Synthesis of vitamins by intestinal bacteria. Natl. Acad. Sci. U.S.A. Proc. 28 : 285-9. 1942.
5. Heiman, V., J. S. Carver and J. W. Cook. The relative vitamin G content of alfalfa hay, stems and leaves from 10 inch and 24 inch cuttings. Poultry Sci. 17 : 412-6. 1938.
6. Hennessy, D. J. A standard thiochrome assay for determination of thiamine in cereal products. A.A.C.C. News Letter, No. 55, p. 25, May 1942.
7. Hunt, C. H., P. R. Record and R. M. Bethke. Influence of stage of maturity on the chemical composition and the vitamin B (B_1) and G content of hays and pasture grasses. Ohio Expt. Sta. Bull. 576. 1936.
8. Vail, C. E., J. W. Tobiska and Earl Douglass. Further studies on vitamins in alfalfa hay. Col. Expt. Sta. Tech. Bull. 18. 1936.

THE EFFECT OF METHOD OF FREEZING, TYPE OF PACK AND STORAGE ON ASPARAGUS TISSUE[1]

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In conjunction with the determination of rates of freezing for several commercially packed vegetables and fruits (2) this investigation was undertaken with a view to ascertaining the extent and location of damage to the tissues by different methods of freezing, packing and periods of storage.

MATERIALS AND METHODS

Unpacked and packed asparagus was frozen by different methods which involved varied rates of freezing. For complete freezing and hardening the freezing period ranged from under 2 minutes to practically 12 hours. The first examination of all products was made approximately 24 hours after placement in the freezing room. At this examination, made in a cold room of + 10° F. to + 20° F. to prevent thawing of the material, freehand and, when possible, microtome sections were cut and examined microscopically. Duplicates were fixed in the chilled fixing solutions. Either a modification of Bouin's solution or form-acetic alcohol was used. The material was then dehydrated in an alcohol series, stained and mounted. A third lot was fixed in the cold room and pumped while thawing in the laboratory. This latter material was dehydrated in an N-Butyl alcohol series, embedded in paraffin and later stained variously, haematoxylin and crystal violet proving the best.

All ice crystals dissolved in the fixing solutions but the patterns of tissue rupture were fixed. Contiguous sections from the same piece of frozen tissue examined while frozen or fixed and mounted in the cold room or sectioned from embedded material indicated the pattern similarity.

Additional material was obtained from beans, strawberries and peas, but frozen strawberries fractured so readily during the sectioning operation that sections for mounting were difficult to obtain, and the hard akenes in the embedded material caused shredding.

Two years' work with Washington asparagus included:

Brine pack, static at −50°, −20° and 0° F.,
Dry pack, contact at −50° and −20° F.,
Dry and brine packs, airblast on product at −50° F., −20° F. and 0° F., packaged after freezing,
Dry and brine packs, immersion of product at −50° F. and at 0° F., packaged after centrifuging the frozen material, and
Dry and brine packs, airblast at −20° F. and at 0° F. on the packaged product.

For static freezing, cylindrical, heavily-waxed, pint cartons were filled with the prepared asparagus spears, covered with 2 per cent NaCl solution then frozen in still air. Contact frozen cartons were of dimensions $5\frac{1}{4}'' \times 5\frac{1}{4}'' \times 2\frac{1}{4}''$ and were placed between metal plates between the expansion coils. Asparagus frozen on agateware trays directly in front of

[1] Contribution No. 673 from the Division of Horticulture, Experimental Farms Service, Ottawa.

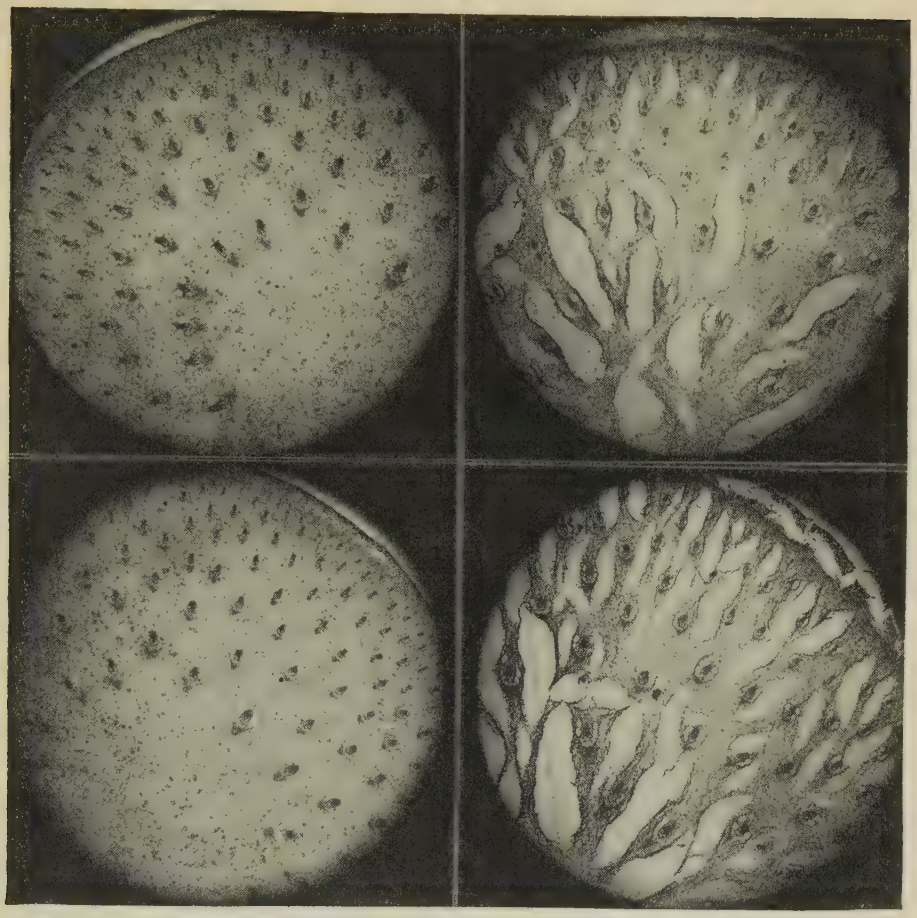

PLATE I: FIGURE 1 (upper left). Cross section of fresh asparagus, 10X
FIGURE 2 (lower left). Cooked unfrozen asparagus, 10X.
FIGURE 3 (upper right). Brine-packed asparagus, frozen static at −50° F. Stored 24 hr. 10X.
FIGURE 4 (lower right). Brine-packed asparagus, frozen static at 0° F. Stored 24 hr. 10X.

fans, then packaged either dry or in two per cent brine, was the method of freezing by airblast on the product. For immersion, the prepared material was placed in wire baskets, the baskets immersed in the freezing solution, centrifuged after freezing, then packaged either dry or in brine. Airblast of 450 l.f.p.m. on the pack is self-explanatory.

RESULTS

Static Freezing

The static brine packs were 60° F. at the time of placement in the freezing rooms. To reach the freezing room temperature the samples frozen at −20° F. required 485 minutes, and those at 0° F., 765 minutes. Figures were not obtained for the −50° F. static freeze but observations and calculations indicate that it should be about 325 minutes.

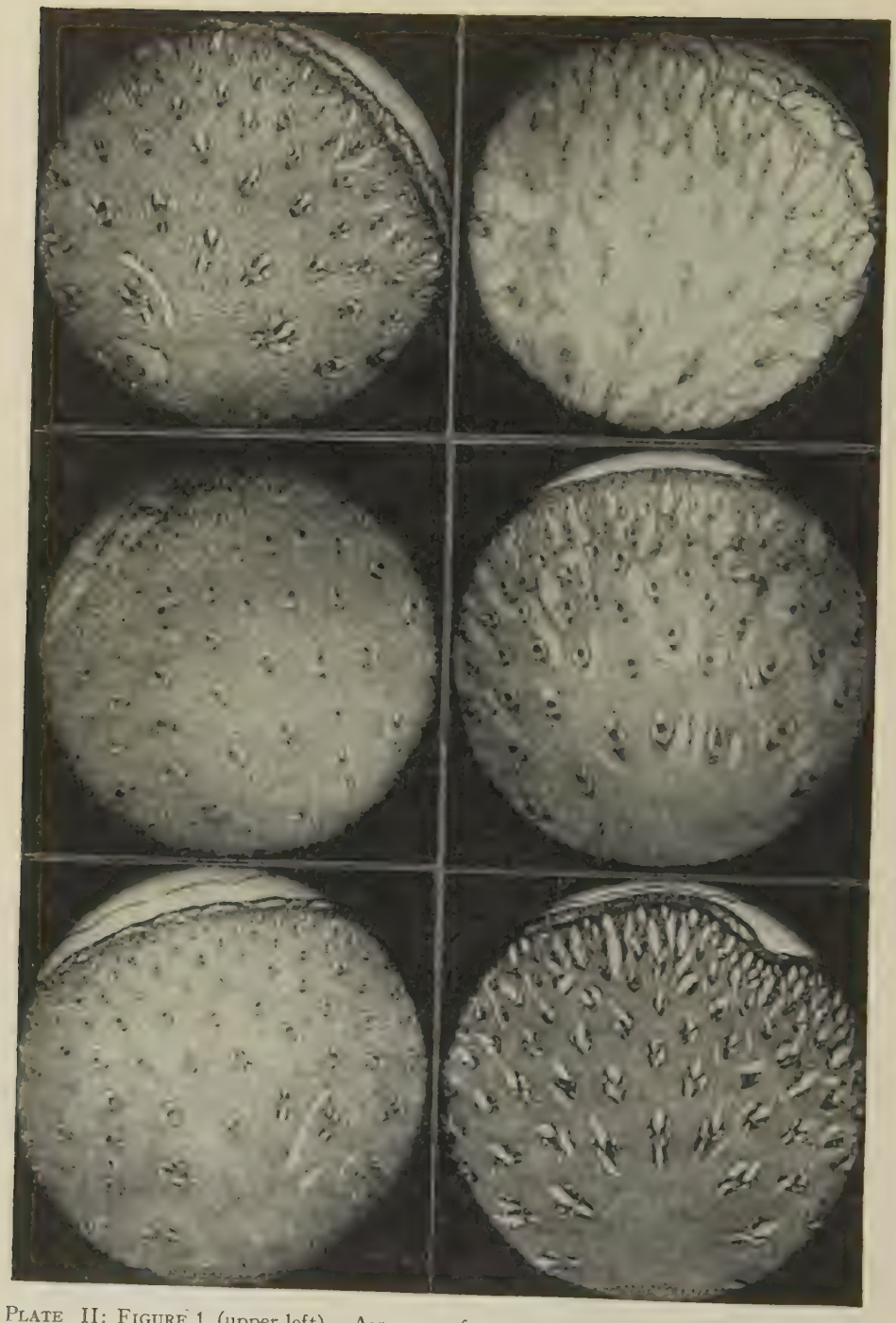

PLATE II: FIGURE 1 (upper left). Asparagus frozen at 0° F. by airblast of 450 l.f.p.m. on the unpacked product. Stored 24 hr. 10X.

FIGURE 2 (centre left). Asparagus frozen at −20° F. by airblast of 450 l.f.p.m. on the unpacked product. Stored 24 hr. 10X.

FIGURE 3 (lower left). Asparagus frozen at −50° F. by airblast of 450 l.f.p.m. on the unpacked product. Stored 24 hr. 10X.

(Continued on page 169)

PLATE II: FIGURE 4 (upper right). *(continued)* Brine-packed asparagus frozen at 0° F. by airblast of 450 l.f.p.m. on the pack. Stored 24 hr. 10X.

FIGURE 5 (centre right). Dry-packed asparagus frozen at 0° F. by airblast of 450 l.f.p.m. on the pack. Stored 24 hr. 10X.

FIGURE 6 (lower right). Brine-packed asparagus frozen at −20° F. by airblast of 450 l.f.p.m. on the pack. Stored 24 hr. 10X.

At the 24-hour examination the tissue of the statically frozen brine-packed asparagus was severely ruptured (Plate I, Figures 3 and 4). The tears in the tissue extended one to several centimeters longitudinally and had a radial diameter of up to one centimeter with a smaller tangential diameter. The tears were smaller, but more numerous near the circumference of the stalk where the bundles were also more numerous. These tears were packed with ice crystals, the crystals in the asparagus frozen at the highest temperature being the largest. However, in these three brine-packed, statically frozen lots it was difficult to obtain microtome sections of the frozen product; the ice crystals "popped" out of lacunae on cutting, and the sections would collapse during transference to the fixing solutions. The large lacunae appeared cross-barred by the regular ice crystal cleavage planes, but the crystals were packed irregularly in the smaller lacunae. The entire stalks of these statically frozen samples were encased in a hull of ice. On sectioning the frozen mass, this hull broke off in flakes and frequently removed areas of epidermis. Just beneath the surface, the larger diameters of the small lacunae were tangential and this assisted in tearing the epidermis during sectioning. The larger lacunae were filled with roughly cubical ice crystals. In the centre of each ice crystal there was one to several small air or gas bubbles. When several were present they were not grouped but in a straight line. There appeared to be a layer of ice-crystals inside the cell close to the cell wall. These could be seen clearly in the product frozen at −50° F., but in the material frozen at higher temperatures it was not possible to cut sections thin enough to determine whether ice formation occurred in the cells or the intercellular spaces.

There were variations in the cavitation pattern, that is, certain samples frozen at −50° F. were very similar to samples frozen at higher temperatures and occasionally one of these latter samples exhibited less cavitation than others frozen more rapidly. Some of these differences were probably due to the physiology of the individual stalk, for it was noted that tips with highly metabolic cells still in the actively dividing or expanding stage, and thus full of cytoplasm with few vacuoles, were more severely torn with flattened and crushed cells. This was the case no matter what the temperature of freezing.

With storage there was, in these cases, an increase of tissue rupture. This increase in the tissue rupture was not so conspicuous in the brine-packed statically frozen material since the lacunae formed by the ice crystals were very large at the first examination.

Contact Freezing

By calculation contact freezing of the dry pack at −50° F. required 170 minutes. By this method of freezing the tissue was not ruptured extensively (Plate III, Figure 3). In the more developed part of the stalk

the tears generally involved the fibrovascular bundles with the conducting tissue torn and the phloem crushed. In rather curved tears between or around bundles the largest was approximately 5 millimeters in radial and 2 millimeters in tangential diameter. At the sides of such cavities the cells were crushed and flattened. The ice crystals here were small. The undamaged cells were fully distended, some with many small ice crystals. In certain cases, the intercellular spaces contained ice crystals; in others, there were none at these locations. Here, as in immersion, the cell sap in general was not withdrawn from cell to intercellular space and therefore was frozen *in situ*. With storage, tearing increased slightly. Contact at −20° F. required 285 minutes for freezing and hardening. Cavitation in these samples (Plate III, Figure 4) was practically as extensive as in the brine pack static freeze at −20° F. requiring 485 minutes.

Freezing by Airblast on the Product

With airblast on the product those samples frozen at −50° F., −20° F. and 0° F. required 11, 18 and 32 minutes, respectively. The period for −20° F. freezing was obtained by observation; the others by calculation. Tearing of the tissue with these methods of freezing was slight (Plate II, Figures 1, 2 and 3). The ice crystals were small and were for the most part in the cells but the cavities were filled. Tearing, in general, involved the fibrovascular bundles but some few cavities appeared between bundles.

Dry-packed asparagus frozen by this method showed an increase of cavitation with storage of 8 to 10 months. This was more noticeable with −50° F. and 0° F. freezing, but those samples frozen at −50° F. were stored at the same temperature for 3 months and at 0° F. for the remainder of the period. The samples packed in brine after freezing were considerably more ruptured by the ice-filled cavities than the dry-packed products and the ice crystals in the cavities were also larger.

Freezing by Immersion

Immersion freezing, the fastest freezing employed, caused the least rupture of the tissues. The freezing period for either −50° F. or 0° F. was not obtained, but at −25° F. the interval required was under 2 minutes. At the first examination asparagus sections from stalks frozen by immersion at −50° F. showed only an occasional broken xylem element in the fibrovascular bundles near the periphery of the stalk (Plate III, Figure 1). The ice crystals were very fine and were definitely within the cells. With immersion at 0° F. a small degree of tissue rupture occurred at the fibrovascular bundles and occasionally between the bundles (Plate III, Figure 2). Small radial tears were closely massed at the periphery.

With storage for 6 months at 0° F. there was practically no increase in tissue rupture of the dry-packed product, but ice-filled lacunae appeared in the centre of the stalks of the brine-packed material. An increase of tissue rupture occurred during storage in both dry and brine packs frozen at −50° F., the rupture in the latter being more extensive than with brine pack at 0° F. Again, this may be due in part to the change of temperature from −50° F. to 0° F. after 3 months of storage.

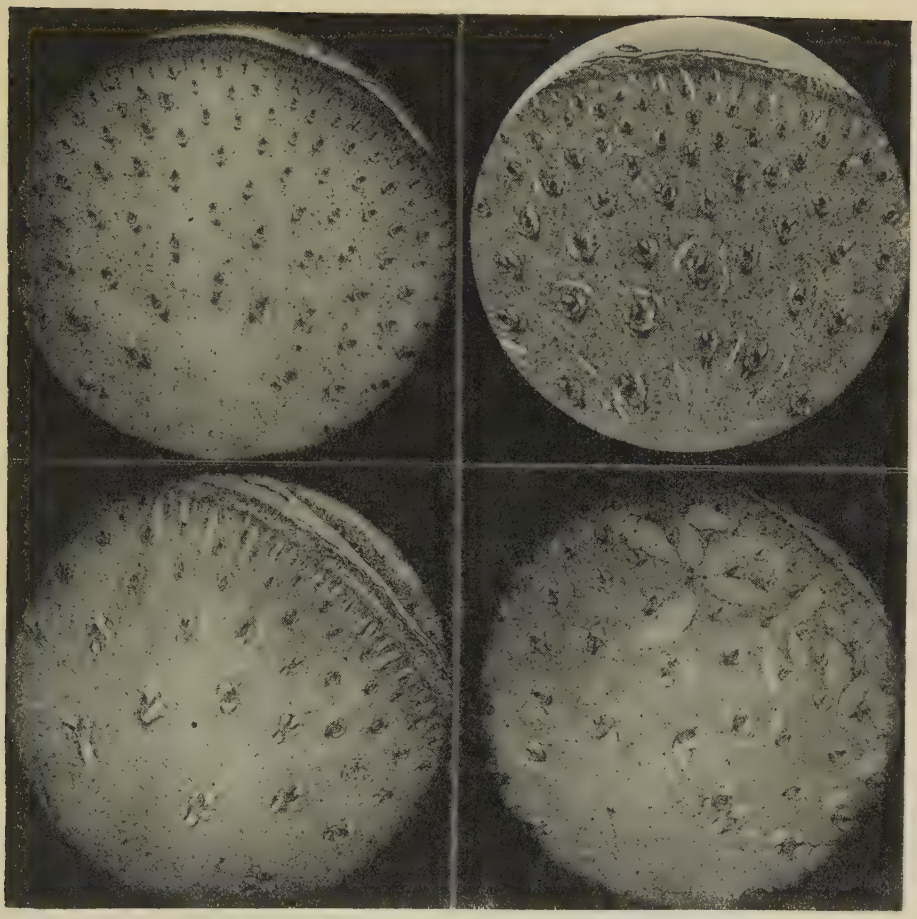

PLATE III: FIGURE 1 (upper left). Asparagus frozen by immersion at −50° F. Stored 24 hr. 10X.
FIGURE 2 (lower left). Asparagus frozen by immersion at 0° F. Stored 24 hr. 10X.
FIGURE 3 (upper right). Dry-packed asparagus frozen at −50° F. by contact of the package with freezer plates.
FIGURE 4 (lower right). Dry-packed asparagus frozen at −20° F. by contact of the package with freezer plates.

Freezing by Airblast on the Packed Product

The freezing and hardening periods for airblast on the brine-packed samples were 165 minutes at −20° F. and 255 minutes for 0° F., while airblast on dry-packed samples at 0° F. took 330 minutes. Although the brine pack (Plate II, Figure 4) was frozen more rapidly than the dry pack (Plate II, Figure 5) there was more extensive rupture of the asparagus tissue and the cavity pattern was quite similar to freezing a brine pack static at 0° F. Tissue rupture of the brine-packed material frozen at −20° F. was quite extensive, involving the vascular bundles and the periphery of the stalk (Plate II, Figure 6). Ice crystals in the −20° F. sample were smaller than in those frozen at 0° F. There was little to no increase of cavitation in these samples with storage at the temperature employed for freezing.

DISCUSSION

There is, of course, no tissue rupture in the fresh product (Plate I, Figure 1). A very few small tears occurred in the fresh cooked material, but bundles were not involved (Plate I, Figure 2). In all frozen asparagus, bundles were more or less involved indicating that breakdown or tearing of tissue at bundles is due to ice crystal formation. This involvement of the bundles whether or not parenchyma tissue is also ruptured has been reported by Woodroof (3). Lee, Gortner and Whitcombe (1) stated that "the slower the rate of freezing, the larger the ice crystals; but in the corresponding thawed samples these differences disappeared, and damage was not apparent." Their photographs of frozen peas and beans show increased cavitation with extended freezing periods and the cavitation is not apparent in the thawed product.

As already stated, the asparagus frozen at this laboratory was examined while frozen and slides were made from material that was fixed while in the frozen state. The material was not allowed to thaw before fixation. However, samples were also obtained from lots which were fixed after cooking the frozen asparagus. The slides—and of course the photomicrographs therefrom—all show the same cavitation as in the frozen product. It would appear that in the thawing the cavities present in the frozen material are obscured by the cytoplasm, water and those organic fragments loosened during cutting and therefore, though not apparent, the cavities are still present.

The larger cavities in slow-frozen brine-packed asparagus, which may extend radially across 125 or more cells and tangentially across 50 cells, are fairly easy to see with the naked eye; but in the fast-frozen product they may be less than a dozen cells in length and four to five, sometimes only one or two, cells in width. Such cavities are not visible to the unaided eye, or they may be occluded by free cytoplasm or cell fragments flooding them during thawing. Unless observed by magnification of the stained thin sections the tissue of airblast frozen asparagus, for example, does not appear to be torn, crushed or disrupted.

Yet the cavitation of slowly frozen or brine-packed products has little effect on the texture to the consumer. This is indicated by taste panel results on beans. The average texture value of 56 samples of cooked brine packed beans was 86.5, and of dry-packed, 86. Seven methods of freezing were included in these tests, but by all methods there were both brine- and dry-packed samples and tissue rupture in the brine pack is relatively greater than in the dry pack frozen by the same method.

When ice-filled cavities extend for as much as 5 centimeters vertically in a stalk of slow-frozen brine-packed asparagus, it is reasonable to deduce that more extensive leaching occurs during the thawing and cooking of the product. However, the average ascorbic acid content of 128 dry packs of beans was 16.9 mg. and of the brine packs 17.2 mg. per 100 gm. of frozen solids. In the cooked products, with approximately half the number of samples, the solids in the dry and brine packs contained respectively 9.7 and 7.34 mg. per 100 gm. The cooking liquids of these contained 3.8 and 3.96 mg./100 gm. based on the solids content. Therefore, although the cooked dry-packed material which had smaller ice-filled cavities in

the frozen product retained more ascorbic acid than the brine-packed, and although the ascorbic acid in the cooking liquid was practically the same, it may be argued that the greater losses in the brine pack were not due to more leaching but to necessarily longer exposure to heat for thawing and cooking. No packs were thawed at room or refrigerator temperature before cooking. On the other hand the cooked values of dry-packed beans frozen by airblast on the pack at −20° F. and by static at 0° F., and therefore with considerable differences in cavitation, averaged respectively 10.5 and 8.2 mg./100 gm. ascorbic acid in the solids. These samples were processed from one lot of beans thus reducing the fresh factor difference. The ascorbic acid contents of the cooking liquids were 2.1 and 3.0. The values of the uncooked frozen products were 12.8 and 12.9. Since the difference between these two lots was a difference in freezing time and consequent difference in tissue rupture only, it is reasonable to conclude that in this case the greater vitamin retention in the cooked solids is due to less tissue rupture in the faster frozen sample.

Although Woodroof *et al.* (4) indicate that "hollowness" of good quality beans is due to overscalding, that is, overblanching, this laboratory has found hollowness occurring in good quality beans with extensive tissue rupture during freezing.

This investigation indicates that tissue rupture is not due to speed of freezing alone. A very important factor is the amount of free moisture in the package; for example, brine-packed vegetables and syrup-packed fruits frozen rapidly may exhibit more tissue rupture than dry packs frozen more slowly. Generally, however, the more slowly either a dry or a "wet" packed product is frozen, the greater is the tissue rupture. One other factor in the extent of tissue rupture is the stage of growth of the product. Succulent growing points with non-vacuolated cells are relatively more torn than those sections which are at a later stage of growth; for example, the tip of asparagus in comparison with the stalk.

In those fissures formed during freezing, the larger ice crystals are found in the more slowly frozen product. In very rapid freezing, as by immersion of the individual pieces in solutions at −50° F. or even at 0° F., small ice crystals are in the cells and in such cavities as occur during freezing. In more slowly frozen products some ice may be found in the cell, but much more is found as a peripheral hull or layer of ice in the inter-cellular spaces and the fissures, proportionately larger, are also filled.

Some of the cavities may be so small as to be invisible without magnification, but with cooking the tears in the tissue do not close and are practically the same as in the frozen product.

SUMMARY

Tissue of asparagus requiring from under 2 minutes to 12 hours for freezing was examined after freezing and after storage periods. Very rap freezing caused little tissue rupture. In brine and dry packs frozen at the same temperature, the brine packs required a shorter interval for freezing but the tissue had larger ice-filled lacunae. Increase of tissue rupture occurred with the addition of chilled solutions to the frozen product and generally the size of the lacunae increased with storage.

ACKNOWLEDGMENTS

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REFERENCES

1. Lee, F. A., W. A. Gortner, and Joanne Whitcombe. Effect of freezing rate on vegetables. Ind. & Eng. Chem. 38 : 341-346. 1946.
2. MacArthur, Mary. Freezing of commercially packaged asparagus, strawberries and corn. Fruit Products J. 24 : 238-240. 1945.
3. Woodroof, J. G. Microscopic studies of frozen fruit and vegetables. Georgia Exp. Sta. Bull. 201. 1938.
4. Woodroof, J. G., I. S. Atkinson, S. R. Cecil, and E. Shelor. Studies of methods of scalding (blanching) vegetables for freezing. Georgia Expt. Bull. 248. 1946.

WASTE SULPHITE LIQUOR SOLIDS AS A SOIL TREATMENT[1]

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The importance of maintaining a satisfactory level of organic matter in soils is well recognized. The chemical composition of soil organic matter, however, is not too well understood. After considerable investigation, Waksman (9) in 1929, stated that "one may then consider soil organic matter to be largely a protein-lignin complex, accompanied by small amounts of celluloses, hemicelluloses, fats, waxes and various other compounds in smaller amounts, all slowly undergoing decomposition". In 1942, Norman (3) observed that "the opinion is now held quite generally that lignin or lignin-derived material contributes substantially to the organic fraction of soils".

It might be assumed, therefore, that the addition of materials high in lignin content should prove of value in maintaining or increasing the organic matter fraction of soil. Wood contains from 25 to 35 per cent of lignin. In the preparation of wood pulp by the sulphite process, the wood is heated with a solution of sulphurous acid and acid sulphites and the lignin is thereby converted into water-soluble lignin sulphonic acids, leaving the cellulose in a more or less pure condition. After removal of the cellulose, the solution containing the lignin sulphonic acids, together with various carbohydrates, organic acids and excess sulphurous acid and sulphites, is called waste sulphite liquor and is usually discarded. Since lignin makes up the largest part of the organic matter of this material, various attempts have been made to use it as a source of soil organic matter. Because it contains practically no nitrogen, phosphorus or potassium, it cannot be considered as a fertilizer.

LITERATURE REVIEW

In 1940, Spulnik *et al.* (7) reported on the effect of adding waste sulphite liquor directly to soil. The experiment was carried out in cans containing 1 lb. of soil and it was shown that, in concentrations below 80 tons per acre, this material was not toxic to sunflowers. On sulphur-deficient soils, it proved to be satisfactory as a source of sulphur. Abstracts of later work by some of these authors (2, 8) indicated that, although the fertilizing value of sulphite waste liquor is low, it can be added to irrigation water at a rate as high as 0.5 inches per acre (60 tons per year), thus affording a means of its disposal.

Phillips *et al.* (5) carried out experiments on the ammonification of waste sulphite liquor and the use of this product as a soil treatment. Greenhouse tests showed that, as a source of nitrogen, the ammoniated material gave increased yields of millet on a Norfolk loamy fine sand, although it was not as efficient as dried blood or a mixture of $NaNO_3$ and $(NH_4)_2SO_4$.

A review of the literature shows that a number of patents for the conversion of waste sulphite liquor into a fertilizer have been taken out in Canada, Germany and the United States. Wood products for fertilizers,

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TABLE 1.—ANALYSIS OF SAMPLES OF WASTE SULPHITE LIQUOR SOLIDS

(Results on air-dry basis)

	No. 1 (NH_4-base, neutralized with NH_3)	No. 2 (Ca-base, neutralized with NH_3)	No. 3 (Ca-base, neutralized with Ca
% N	3.80	2.40	<0.10
% S	8.23	7.10	7.10
% ash	1.27	9.66	11.30

including waste sulphite liquor, were discussed (4) at a conference at Orono, Maine, in 1945. Recently, Sauchelli (6) in a review presented some preliminary results by various workers which indicated that waste sulphite liquor or a product derived from it may be of some value in increasing crop yields and as a treatment for improving the structure of the soil.

MATERIALS INVESTIGATED

During the past two years, greenhouse experiments on the use of a waste sulphite liquor product as a soil treatment and its effect on crop growth have been carried out by the Division of Chemistry, Science Service, Central Experimental Farm, Ottawa. Three different materials[1] have been investigated. Sample No. 1 was prepared from an ammonium-base cooking liquor by neutralizing with ammonia; sample No. 2 was from a calcium-base cooking liquor which was neutralized with ammonia; sample No. 3 was from a calcium-base cooking liquor which was neutralized with calcium hydroxide. The materials were received in the form of a dry powder and the results of analysis for total nitrogen, total sulphur and ash are presented in Table 1. The nitrogen content was highest in sample No. 1 and somewhat less in sample No. 2. There was practically no nitrogen in the third sample which did not have ammonia added at any time. The sulphur content showed much less variation among the samples and the ash increased as more calcium was used in the preparation.

GREENHOUSE EXPERIMENT, 1945-46

The first experiment was carried out in 1945-46 using sample No. 1 (from NH_4-base liquor, neutralized with NH_3) on a soil classified as Rideau clay, sand spot phase, but from a field of low fertility. The treatments were: (1) check—no treatment; (2) waste sulphite liquor solids (hereinafter referred to as W.S.L.S.) at 10 tons per acre; (3) dried manure to supply an amount of nitrogen equal to that in treatment 2; (4) W.S.L.S. supplemented with phosphorus as $CaH_2(PO_4)_2$ and potassium as KCl equal to that in the manure; (5) an NPK treatment equivalent to a 2-12-10 fertilizer at 1000 lb. per acre; (6) W.S.L.S. supplemented with P and K equal to that in the NPK treatment; (7) a PK treatment at the same rates as in treatments 5 and 6. The amounts of nitrogen, phosphorus and potassium applied by each treatment and expressed in grams per pot are given in Table 2. The lower rates of application of phosphorus and potassium are designated P_1K_1, the higher rates P_2K_2.

[1] Supplied by the Canadian International Paper Co., Hawkesbury, Ont.

TABLE 2.—AMOUNTS OF N, P AND K SUPPLIED BY TREATMENTS (1945-46)

(Expressed in grams per pot)

Treatment	N	P	K
1. Check	—	—	—
2. W.S.L.S.[1]	0.861	—	—
3. Manure	0.861	0.318	0.706
4. W.S.L.S. + P_2K_2	0.861	0.318	0.706
5. N P_1K_1	0.023	0.059	0.094
6. W.S.L.S. + P_1K_1	0.861	0.059	0.094
7. P_1K_1	—	0.059	0.094

[1] W.S.L.S. =Waste sulphite liquor solids.

These treatments were added to 5 lb. of soil, thoroughly mixed and put in half-gallon pots. There were four replicates of each treatment. Ten oat seeds were planted in each pot and, shortly after germination, these were thinned to six per pot. The plants were harvested 134 days after planting and allowed to air-dry before yields were determined. Results for grain and for the entire plant are presented in Table 3, arranged in order of increasing yields, and show the mean values of four replicates expressed in grams per pot.

RESULTS OBTAINED, 1945-46

In this experiment, agreement among replicates was very good and, where definite increases were obtained, there was no overlapping of values between treatments. Manure alone gave no increase in yield even though it contained considerable amounts of nitrogen, phosphorus and potassium. Previous experience has shown that dried manure in greenhouse work is frequently not beneficial. There was no increase in grain yield but a considerable increase in the total weight for the P_1K_1 treatment; the addition of a small amount of nitrogen to the P_1K_1 resulted in definite gains. Yields of both grain and entire plants were very greatly increased by the W.S.L.S. which contained much larger amounts of nitrogen than the NPK fertilizers used. These results were still further improved as the rates of phosphorus and potassium applied were increased. From this experiment, it can be concluded (*a*) that oats grown on the soil used responded to applications of nitrogen, and also to applications of P and K when N was supplied; and (*b*) that the nitrogen in the W.S.L.S. was readily available to the oats.

GREENHOUSE EXPERIMENT, 1946-47

A second experiment was carried out in 1946-47, using samples 2 and 3 of the sulphite material on two soil types, Uplands sand and North Gower clay loam. The treatments used were: (1) check—no treatment; (2) manure at 15 tons per acre supplemented with additional phosphorus; (3) W.S.L.S. sample No. 2 containing the same amount of nitrogen as the manure; (4) W.S.L.S. as in treatment 3 supplemented with the amount of P and K added in the manure; (5) nitrogen, as urea, equal in amount to that in the manure; (6) NPK, as urea, monocalcium phosphate and potassium sulphate, equal to the quantities in the manure treatment;

TABLE 3.—AVERAGE YIELDS OF OATS IN 1945-46 EXPERIMENTS

(Expressed in grams per pot)

Treatment	Grain	Entire plant
Check	1.7	3.9
Manure	1.7	4.3
P_1K_1	1.7	4.9
N P_1K_1	2.8	7.4
W.S.L.S.[1]	5.1	12.2
W.S.L.S. + P_1K_1	8.3	19.0
W.S.L.S. + P_2K_2	17.1	37.1

[1] W.S.L.S. =Waste sulphite liquor solids.

(7) sulphur as gypsum, equal to that in the W.S.L.S.; (8) S + N as in treatments 7 and 5; (9) S + NPK as in treatments 7 and 6; (10) W.S.L.S. sample No. 3 at the same rate as sample No. 2; (11) W.S.L.S. sample No. 3 supplemented with N, as urea, equal to that used in previous treatments; (12) W.S.L.S. sample No. 3 supplemented with NPK as in treatment 6. A summary of the quantities of these elements in the different treatments, expressed in grams per pot, is given in Table 4.

The treatments were mixed with the soil and placed in pots as in the previous experiment, but only three replications were used. Nine oat seeds were planted in each pot at 1″ depth and inoculated seeds of alfalfa at $\frac{1}{2}$″ depth. After germination, these were thinned to four oats and six alfalfa plants. The alfalfa was allowed to grow for some time after the oats were harvested. A total of three cuttings of alfalfa was obtained before the experiment was terminated, the sum of these being taken as the total yield of alfalfa per pot. The results for the two crops, expressed on the air-dry basis, are given in Tables 5 and 6 and show the mean values of three replicates expressed in grams per pot.

RESULTS OBTAINED, 1946-47, OAT CROP

The data obtained were analysed for variance. In the case of the yields of oats, it appeared from the individual pot yields that the range of values in each set of triplicates was related to the mean and that treatment differences were large. It was decided, therefore, to analyse the data in two groups and the necessary difference for significance between treatments is given at the bottom of the table for each group.

On both soils, the largest yields were obtained with the NPK and S + NPK treatments, the third largest with NPK + sample No. 3. Sulphur, as gypsum, had no apparent effect on yield. However, sample No. 3 which supplied S but not N, P or K had an adverse effect. On the Uplands sand, oats responded well to nitrogen applications, the nitrogen of urea being very much more available than that of the W.S.L.S. The nitrogen of the latter was apparently available to some extent as shown by comparing the yield from W.S.L.S. No. 2 treatment (2.5 gm.) with that from W.S.L.S. No. 3 treatment (0.2 gm.) or from sulphur alone (0.4 gm.). On this soil, PK when applied with N or with S + N gave significant increases in grain yield, but not when applied with either W.S.L.S. sample.

TABLE 4.—AMOUNTS OF N, P, K AND S SUPPLIED BY TREATMENTS (1946-47)

(Expressed in grams per pot)

Treatment	N	P	K	S
1. Check	—	—	—	—
2. Manure + P	0.185	0.142	0.238	—
3. W.S.L.S. (No. 2)	0.185	—	—	0.512
4. W.S.L.S. (No. 2) + PK	0.185	0.142	0.238	0.512
5. N[1]	0.185	—	—	—
6. NPK	0.185	0.142	0.238	—
7. S[2]	—	—	—	0.512
8. S + N	0.185	—	—	0.512
9. S + NPK	0.185	0.142	0.238	0.512
10. W.S.L.S. (No. 3)	—	—	—	0.512
11. W.S.L.S. (No. 3) + N	0.185	—	—	0.512
12. W.S.L.S. (No. 3) + NPK	0.185	0.142	0.238	0.512

[1] As urea. [2] As gypsum.

On the North Gower clay loam, response to nitrogen was good when the phosphorus and potassium were applied but not when they were omitted from the treatments. Where response was obtained, the nitrogen of urea was again found to be more available than that of the W.S.L.S. On this soil, the application of PK in every case gave increased yields, regardless of what other treatments were used with it.

Manure on Uplands sand where oats responded to nitrogen, gave no significant increase in grain yields over the check, whereas the W.S.L.S. sample No. 2 (containing N) gave a significant increase. Manure on North Gower clay loam where oats responded to phosphorus and potassium, did give a significant increase in grain yield over the check; on the other hand, the W.S.L.S. sample No. 2 gave no increase until it was supplemented with PK.

RESULTS OBTAINED, 1946-47, ALFALFA CROP

In studying the alfalfa yields, those from the North Gower clay loam were analysed for variance in two groups as was done with the yields of oats. On the Uplands sand, however, the alfalfa yields were so variable, it seemed that the best method to use was the ordinary analysis for variance. The necessary differences for significance are given at the bottom of Table 6.

Sulphur had no beneficial effect on the alfalfa but, in two cases, reduced yields on the North Gower clay—when applied alone in W.S.L.S. sample No. 3 and when applied as gypsum with NPK. Alfalfa, as was to be expected, did not respond to applications of nitrogen in any of the forms applied. In general, the largest yields were obtained where phosphorus, or phosphorus and potassium, were applied in the form of inorganic salts. This was particularly true on the North Gower clay loam. On the Uplands sand, where N, P and K were applied as chemically pure compounds, the alfalfa yields were somewhat lower than might have been expected, probably due to the fact that the grain yields on these three treatments were high which may have depleted the sand of the available supply of the required nutrients. It can be concluded from the results presented that the waste sulphite liquor solids used here had little or no effect on alfalfa yields on either soil.

TABLE 5.—AVERAGE YIELDS OF OATS IN 1946-47 EXPERIMENT

(Expressed in grams per pot)

Treatment	Uplands		North Gower	
	Grain	Entire plant	Grain	Entire plant
1. Check	0.6	3.4	0.8	4.1
7. S	0.4	3.1	0.8	4.2
10. W.S.L.S. (No. 3)	0.2	1.5	0.4	2.6
2. Manure + P	0.9	5.1	1.7	6.5
3. W.S.L.S. (No. 2)	2.5	10.3	0.5	3.4
11. W.S.L.S. (No. 3) + N	5.9	17.0	0.4	3.1
5. N	5.4	16.5	1.1	6.8
8. S + N	5.4	19.3	0.8	5.8
4. W.S.L.S. (No. 2) + PK	3.4	10.3	2.7	9.8
12. W.S.L.S. (No. 3) + NPK	6.4	19.0	6.1	16.8
9. S + NPK	8.6	23.0	8.1	21.7
6. NPK	8.6	24.0	8.5	21.9

Nec. diff. for sig. between first four treatments for grain on Uplands =0.4.
Nec. diff. for sig. between last eight treatments for grain on Uplands =1.2.
Nec. diff. for sig. between first eight treatments for grain on North Gower =0.3.
Nec. diff. for sig. between last four treatments for grain on North Gower =2.7.

TABLE 6.—AVERAGE YIELDS OF ALFALFA IN 1946-47 EXPERIMENT

(Expressed in grams per pot)

Treatment	Uplands	North Gower
1. Check	6.3	3.5
7. S	5.9	3.4
10. W.S.L.S. (No. 3)	4.9	2.4
3. W.S.L.S. (No. 2)	1.5	2.6
11. W.S.L.S. (No. 3) + N	3.4	2.6
5. N	3.2	2.5
8. S + N	3.3	2.3
2. Manure + P	16.4	18.1
4. W.S.L.S. (No. 2) + PK	10.3	20.0
12. W.S.L.S. (No. 3) + NPK	8.2	21.6
9. S + NPK	5.8	14.7
6. NPK	7.9	21.2

Nec. diff. for sig. between means on Uplands =3.8 gm.
Nec. diff. for sig. between first 7 treatments on North Gower =1.1 gm.
Nec. diff. for sig. between last 5 treatments on North Gower =6.3 gm.

TABLE 7.—NITROGEN DISTRIBUTION IN W.S.L.S. SAMPLES

Sample	Total N (% of sample)	NH_3-N (% of total N)	$KMnO_4$-sol.-N (% of total N)
1	3.80	86.1	91.5
2	2.40	32.8	51.5

LABORATORY STUDY

A comparison of the two sets of experiments indicated that the availability of the nitrogen in sample No. 2 prepared from a calcium-base liquor neutralized with ammonia was much less than that in sample No. 1 from an ammonium-base liquor neutralized with ammonia. An attempt was made to determine if there were some difference in the chemical nature of the nitrogen in the two samples. Ammonia-N was measured by distillation from $Ca(OH)_2$. Permanganate-soluble-N was determined as outlined for water-insoluble organic nitrogen distilled from alkaline permanganate in the measurement of nitrogen activity by the A.O.A.C. method for fertilizers (1). Due to the high solubility of the materials in water, however, unleached samples were used. The results are presented in Table 7. It is readily seen that the amounts of NH_3-N and of nitrogen obtained after oxidation of the unleached material with alkaline permanganate are much greater in sample No. 1 in which, from the greenhouse results, the nitrogen was more readily available to plants. Nitrification studies now being conducted in the laboratory indicate that the nitrogen of sample No. 1 is oxidized to the nitrate form much more readily than that of sample No. 2.

DISCUSSION

The investigation into the use of waste sulphite liquor solids as a soil treatment is being continued. The possibilities of this material as a source of soil organic matter can be determined only over a period of years. There is some indication that it has an important effect on the physical structure of the soil. This has been mentioned by other workers and will be investigated further in these studies. The immediate value of this product in crop production will depend on its content of readily available plant food constituents. Analyses have shown that it contains practically no phosphorus or potassium. A considerable amount of calcium is present but this element is more readily supplied to soils, when needed, in the form of limestone or gypsum. Sulphur is present in large quantities and, although experiments reported herein have shown no beneficial effect from this element, the waste sulphite material may be of importance on sulphur-deficient soils. Nitrogen may be present if an ammonium bisulphite solution is used as the cooking liquor or if the ordinary calcium-base liquor is neutralized with ammonia. Materials from these two sources have been used in experiments outlined above.

In 1945-46, a sample prepared from an ammonium-base cooking liquor was used on a soil classified as Rideau clay, sand spot phase and taken from a field of low fertility. Oats responded to applications of nitrogen and of waste sulphite liquor solids. Yields were still further increased when phosphorus and potassium were supplied with the latter. The nitrogen of this sample of W.S.L.S. appeared to be readily available to the indicator crop used.

In 1946-47, a sample from a calcium-base cook neutralized with ammonia and one from a similar cook neutralized with lime were used on Uplands sand and North Gower clay loam. Oats and alfalfa were grown. On the Uplands sand, oats responded to applications of nitrogen, but the nitrogen of urea was apparently much more available than that of the

W.S.L.S. sample No. 2. On North Gower clay loam, oats responded to applications of phosphorus and potassium. When these elements were supplied, there was also some response to nitrogen but again the response was greater when the nitrogen was supplied in urea than in W.S.L.S. sample No. 2.

SUMMARY

Greenhouse experiments on the use of waste sulphite liquor solids as a soil treatment and their effect on crop growth have been conducted for two years by the Division of Chemistry, Science Service.

Three materials have been investigated: (1) from an ammonium-base cooking liquor neutralized with ammonia, containing 3.8 per cent N; (2) from a calcium-base cooking liquor neutralized with ammonia, containing 2.4 per cent N; (3) from a calcium base cooking liquor neutralized with $Ca(OH)_2$, containing less than 0.1 per cent N. All samples contained 7 per cent to 8 per cent S.

On soils where oats responded to applications of nitrogen, response to additions of waste sulphite liquor solids containing nitrogen was also obtained. The nitrogen of sample No. 1 was appreciably more available to the plants than that of sample No. 2.

When alfalfa was grown it responded to applications of phosphorus and potassium but not of nitrogen. The W.S.L.S. samples had little or no effect on the growth of alfalfa.

Sulphur, whether applied as gypsum or with the W.S.L.S., had no beneficial effect on the growth of either oats or alfalfa.

Since these studies indicated that the nitrogen of sample No. 2 (from Ca-base liquor, neutralized with NH_3) was less available to plants than that of sample No. 1 (from NH_2-base liquor, neutralized with NH_3) some chemical examination of the materials was made. This showed that the ammonia nitrogen and the nitrogen obtained after refluxing with alkaline potassium permanganate solution were considerably less in sample No. 2 than in sample No. 1.

REFERENCES

1. Association of Official Agricultural Chemists. Official and tentative methods of analysis (6 edn.), pp. 29-31. 1945.
2. Bollen, W. B. Decomposition of sulfite waste liquor in soils. Pacific Pulp and Paper Ind. 16 : 30-34. 1942. Chem. Abs. 37 : 3600. 1943.
3. Norman, A. G. Soil organic matter: I. Problems in the chemistry of soil organic matter. Proc. Soil Sci. Soc. Amer. 7 : 7-15. 1943.
4. Northeastern Wood Utilization Council, New Haven, Conn. Wood products for fertilizer. Bull. 7. October, 1945.
5. Phillips, M., M. J. Goss, B. E. Brown and F. R. Reid. The ammoniation of waste sulphite liquor and its possible utilization as a fertilizer material. J. Agr. Res. 53 : 209-224. 1936.
6. Sauchelli, Vincent. Lignin: Fertilizer material or soil amendment. Amer. Fert. 104 (No. 3) : 7-9, 28, 30. 1946.
7. Spulnik, J. B., R. E. Stephenson, W. E. Caldwell and W. B. Bollen. Effect of waste sulfite liquor on soil properties and plant growth. Soil Sci. 49 : 37-49. 1940.
8. Stephenson, R. E. Fertilizing value of sulfite waste liquor used on soils in irrigation waters. Pulp and Paper Ind. 19 : 68-70. 1945. Chem. Abs. 40 : 4162. 1946.
9. Waksman, S. A. Chemical and microbiological processes involved in the decomposition of organic matter in nature. Proc. International Cong. Forestry Expt. Sta., Stockholm, pp. 507-514. 1929.

THE STABILITY OF CAROTENE IN CARROTS DURING STORAGE[1]

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For live stock one of the main sources of vitamin A is its precursor, carotene, found in green roughages. During storage in the winter these roughages lose much of their carotene content (2, 4, 5, 7). The result is that in late winter and early spring there may actually be a deficiency (3) of carotene in the rations. Another source of vitamin A is roots such as carrots (8). These are stored in a root cellar and the question arose as to whether under good storage conditions the carotene might be retained in them. If this were so, then in the late winter and early spring a supply of carrots would furnish carotene in the rations.

This experiment was initiated in 1944. It was intended to determine to what extent carrots retained their value as a source of carotene throughout the storage period. The carrots were grown and stored by the Forage Division, Central Experimental Farm. It was found in the preliminary investigation in 1944 that there was considerable variation between roots. For this reason groups of twenty-five roots were used in 1945 and 1946. In each year four groups of 25 carrots were selected at random when the carrots were harvested in the fall. This was done again at two dates during the winter storage and at the conclusion of the storage period in the spring. The final date varied somewhat from year to year due to weather conditions.

The carrots were washed and wiped. The tops were cut off and the roots put through a power grinder. The ground carrot was well mixed and triplicate samples were immediately taken for dry matter (100 gm.) and carotene (10 gm.) determinations. The samples for dry matter were dried at 70° C. in a forced circulation air oven so as not to destroy the sugar.

Carotene was determined by the Peterson and Hughes (1) method, slightly modified. The sample was refluxed with 10 per cent alcoholic KOH and extracted with "Skellysolve". The residue was then ground with sand and refluxed a second time with alcoholic KOH. This was extracted with "Skellysolve" until no more colour could be extracted. The combined extracts were washed with water in a separatory funnel until the alkali was removed. Since it was found in the preliminary investigation that no colour was removed by methyl alcohol extraction this was therefore omitted in 1945 and 1946. The carotene was determined colorimetrically in "Skellysolve" solution in a Klett-Summerson photoelectric colorimeter and compared with a standard curve.

All three varieties of carrots used showed the same trend but there were differences between the two years. In each year there was more carotene per 100 gm. at the end of the storage period than at the beginning; this was true on both original and dry matter bases.

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In the following table each figure is the mean of 12 analyses, representing triplicate determinations on four samples of 25 carrots each.

TABLE 1.—CAROTENE MG./100 GM.
(Dry matter basis)

Date	Oxheart	Nantes	Chantenay	Mean
		1945 crop		
Oct. 1945	33.6	48.3	39.8	40.6
Dec. 1945	48.1	60.2	57.6	55.3
Feb. 1946	49.1	72.6	69.4	63.7
April 1946	45.4	67.3	63.9	58.9
		1946 crop		
Nov. 1946	58.6	74.4	65.3	66.1
Dec. 1946	71.8	83.2	72.3	75.7
Feb. 1947	57.6	61.8	65.3	61.6
Mar. 1947	89.8	79.7	86.3	85.2

The variation in carotene, on the dry matter basis, due to length of storage, was significant at the 1 per cent level in both the 1945 and 1946 crops. The carotene content appears to increase sharply during the earlier part of the storage period. The reason for this may be activity in the carrot root, or it may be an artefact and the apparent increase due to loss of other constituents. This problem is being further investigated.

Somewhat similar results were obtained by Lee and Tapley in their comparison of frozen and root cellar storage (6). They state that carotene is slightly lower in the spring; but when these results are calculated to the dry matter basis the carotene is higher than at harvest.

SUMMARY AND CONCLUSION

The carotene content of carrots during winter storage in a root cellar was investigated.

The apparent carotene content on both the fresh and dry matter basis was greater at the end of the storage period than at the beginning.

Properly stored carrots should provide a good source of carotene for live stock feeding during the winter and early spring when other sources are inadequate.

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REFERENCES

1. Association of Official Agricultural Chemists. Methods of Analysis, p. 369. 1940.
2. Bolin, D. W. Stability of carotene in green grasses and alfalfa stored at 5° F. J. Dairy Sci. 22 : 111-113. 1939.
3. Flora, C. C., *et al.* Carotene in the nutrition of dairy calves. J. Dairy Sci. 22 : 321-328. 1939.
4. Kane, E. A., H. G. Wiseman, and C. A. Carey. The loss of carotene in hays and alfalfa meal during storage. J. Agric. Research, 55 : 837-847. 1937.
5. Kon, S. K., and S. Y. Thomson. Factors affecting the stability and estimation of carotene in artificially dried grass and hays. Agric. Sci. 30 : 622-638. 1940.
6. Lee, F. A., and W. T. Tapley. Carotene retention in carrots. Food Technology 1 : 307-309. 1947.
7. Taylor, M. W., and W. C. Russell. Stability of carotene in plant tissues. J. of Nutrition 16 : 1-13. 1938.
8. Wells, J. G., Jr., and J. A. Davidson. Carrots used for green feed substitute (for poultry). Mich. State Quarterly 23 : 155-158.

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2. U.S. Dept. of agriculture. Commodity credit administration. Report, 1947. Wash., 1947. 13 p.

AGRICULTURAL EDUCATION

3. Statistics of land-grant colleges and universities, year ended June 30, 1946. Wash., 1947. 46 p. (U.S. Office of education bulletin no. 14, 1947)
4. Eight scholarships to encourage forest insect control. Ottawa (1947) 2 p. (processed) (Canada). Dept. of reconstruction and supply. (R. & S. 350)

AGRICULTURAL ENGINEERING

5. German agricultural engineering industry. Reported by H. T. Horsman and others. London, H.M. stationery office, 1946. 35 p. (processed) (British intelligence objectives sub-committee. Final report no. 829. Item no. 31)
6. Barn hay-curing systems; advantages, design, construction and operation. J. H. Ramser. Urbana, 1945. 13 p. (processed) (Illinois. University. College of agriculture. Agricultural experiment station. A Eng. 462)
7. How to select and use concrete blocks in farm building. E. S. Holmes. Lexington, 1947. 12 p. figs. (Kentucky. University. College of agriculture and home economics. Agricultural extension division. Circular 434)
8. Roof covering for farm buildings and their repair. A. D. Edgar and T. A. H. Miller. Wash., 1948. 30 p. figs. tabs. (U.S. Dept. of agriculture. Farmers' bulletin 1751, revised)
9. Electric heat for curing and storing sweet potatoes. Progress report, 1945. Knoxville, Tennessee Valley Authority. Commerce department. Agricultural engineering division, 1946. 7 p. figs. (processed) (Special report no. 31)
10. Progress report on drying hay by forced circulation of air. Prepared by A. T. Hendrix and G. E. Zerfoss (Agricultural engineering division, Commerce department) Knoxville, Tennessee Valley Authority, 1947. 7 p. figs. (processed) (Special report no. 34)
11. Institution of British agricultural engineers. Proceedings. Vol. IV, No. 3-5, December, 1947. London, 76 p.
    Contents: Wheels, tracks and half tracks, by H. J. Hine and others; Ploughs and ploughing, by J. C. Hawkins; Annual general meeting, June 1947; Milking machines, by H. S. Hall; Recent trends in farm engineering, by C. Culpin.
12. Mechanization of the sugar beet harvest in North America. London, H.M. stationery office, 1947. 20 p. il. (Great Britain. Ministry of agriculture and fisheries. Agriculture overseas. Report no. 4)
13. Progress of farm mechanization. Martin R. Cooper and others. Wash., 1947. 101 p. figs. tabs. (U.S. Dept. of agriculture. Miscellaneous publication no. 630)
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15. When you build or remodel your farmhouse; a guide to planning. Urbana, 1948 48 p. il. (Illinois. University. College of agriculture. Extension service circular 620)
16. Your farmhouse . . . planning the bathroom. Wash., 1948. 15 p. figs. (U.S. Dept. of agriculture. Miscellaneous publication no. 638)
17. Simple plumbing repairs in the home. George M. Warren. Wash., 1948. 14 p. figs. (U.S. Dept. of agriculture. Farmers' bulletin no. 1460, revised)

BACTERIOLOGY

18. Society for applied bacteriology. Proceedings, 1946. Leeds, The society, 1947. pp. 1-104. (1946, nos. 1 and 2).
19. The influence of molybdenum, calcium and agar on nitrogen fixation by Azotobacter indicum. H. L. Jensen. (In Linnean society of New South Wales. Proceedings. Vol. LXXII, Parts 5-6, 1947. Nos. 333-334. pp. 299-310)
20. Some aspects of microbiological research in Germany. Reported by R. Y. Stanier. London, H.M. stationery office (1946) 15 p. (processed) (British intelligence objectives sub-committee final report no. 691. Item no. 24)

BEES—HONEY

21. Observations on the performance of package bee colonies in Michigan. R. H. Kelty. East Lansing, 1948. 37 p. figs. tabs. (Michigan state college. Agricultural experiment station special bulletin 344)
22. Modified two-queen system for honey production. W. E. Dunham, Columbus, 1947. 16 p. figs. (Ohio state university. Agricultural extension service bulletin no. 281)
23. Honey and honey cookery. Winston E. Dunham. Columbus, 1947. 31 p. figs (Ohio state university. Agricultural extension service bulletin no. 282)

BOTANY

24. Plants and environment; a textbook of plant autecology. R. F. Daubenmire. New York, John Wiley and sons, inc., 1947. 424 p. figs. Literature cited: pp. 381-409.
25. The genus Crepis. Part one. The taxonomy, phylogeny, distribution, and evolution of Crepis. Part two. Systematic treatment. Ernest Brown Babcock. Berkeley, 1947. pp. 1-198, 199-1030. figs. plates. References: pp. 175-184 (pt. 1) (California. University. Publications in botany. Volumes 21 and 22)
26. A review of the Gasteromycetes (fungi) of Western Pennsylvania. LeRoy K. Henry. Pittsburgh, 1947. pp. 339-363. (Annals of the Carnegie museum. Vol. XXX. article XX)

CHEMIC TECHNOLOGY

27. American society of brewing chemists. Proceedings of the annual meeting, 1947 Chicago, 1947. 147 p. figs. tabs.
28. XI International congress of pure and applied chemistry. London, 1947, Congress lectures. London, 1948. 28 p. (Supplement to "Chemistry & industry," 1948)
    Titles of lectures: Molecular structure and biological specificity, by L. Pauling; Some recent results in organic chemistry, by P. Karrer; Recent developments in electrophoresis, by A. Tiselius; Simplex non veri sigillum, by B. C. P. Jansen; The part of chemistry in the new therapeutics, by Sir Henry Dale; Le carbure de calcium et ses propriétés reductrices, by L. Hackspill.
29. German vegetable parchment industry. Reported by Julius Grant and others. London H.M. stationery office (1946) 40 p. diagr. (processed) (British intelligence objectives sub-committee final report no. 1137. Item no. 22)
30. National soybean processors association. Year book and trading rules, 1947-1948. Chicago, The association, 1948. 68 p.
31. A partial bibliography relating to agar. Leonard S. Stoloff. Wash., 1947. 20 p. (processed) (U.S. Dept. of the interior. Fish and wildlife service. Fishery leaflet 261)
32. Chemical upgrading of agricultural products. W. L. Semon. Columbus, National farm chemurgic council, 1947. 7 p. (processed) (Chemurgic papers. 1947 series no. 5. No. 617)
33. The availability of vegetable tannins. R. M. Loller and Fred O'Flaherty. Columbus. 1947. 12 p. (processed) (National farm chemurgic council. Chemurgic papers. 1947 series no. 5. No. 615)
34. Flavoring materials from domestic crops. Fred J. Triest. Columbus, 1947. 7 p. (processed) (National farm chemurgic council. Chemurgic papers. 1947 series no. 5. No. 616)
35. Effect of alcoholic fermentation and growing of fodder yeast on B.O.D. of sulfite waste liquor. Richard G. Tyler. Seattle, 1947. (Washington. University. Engineering experiment station reprint no. 6) (Reprinted from Sewage works journal . . . January, 1947. pp. 70-74)
36. The determination of alcohol. J. R. Nicholls. London, The Royal institute of chemistry of Great Britain and Ireland, 1948. 26 p. figs. (Third Tatlock memorial lecture)
37. New horizons in animal nutrition and farm chemurgy (II) H. J. Prebluda. Columbus, National farm chemurgic council, 1947. 9 p. (processed) (Chemurgic papers. 1947 series no. 4. No. 591)

COOPERATION

38. Revenue revisions, 1947-48. Hearings before the Committee on ways and means. House of representatives . . . on proposed revisions of the internal revenue code, Part 4. Tax-exempt organizations (Cooperative organizations), 1947. Wash. 1948. pp. xiii, 1867-3161)
39. The Maritime co-operative services . . . Lyn Harrington. (In Farmer's magazine. January, 1948, pp. 7, 35-6)
40. Income taxation of farmer cooperatives. W. E. Rumble. Wash., National cooperative milk producers federation, 1948. 16 p. (Educational series no. 35)
41. North Dakota. Dept. of agriculture and labor. Division of cooperatives. Sixth annual statistical report, 1947. Bismarck, 1947. 16 p. (Bulletin no. 65)
42. A dairy policy . . . 1948. Wash., The national cooperative milk producers federation, 1947. 18 p. (Educational series. no. 34)

DAIRY INDUSTRY—DAIRY RESEARCH

43. Outlook for dairy production in 1948. B. A. Campbell. (In Canadian dairy and ice cream journal, January, 1948. pp. 56-60)
44. French dairy situation . . . (In Foreign crops and markets, February 2, 1948. pp. 81-2)
45. Concentrated sour skim milk. Wash., 1947. 5 p. (processed) (U.S. Dept. of agriculture. Bureau of dairy industry. BDIM-Inf-52)
46. The utilization of whey; a review, by B. H. Webb and Earle O. Whittier. (In Journal of dairy science, February, 1948. pp. 139-164)
47. The milk marketing board. R. A. Pepperall. Thames Ditton, Surrey, England, 1948. 106 p. il.
48. Homogenization of market milk. E. G. Hood and A. H. White. Ottawa, Dominion department of agriculture, 1947. 15 p. (processed) References: pp. 14-15.
49. Testing milk and milk products. W. D. Swope. State College, 1947. 38 p. figs. (Pennsylvania state college. Agricultural extension service circular 308)
50. Manitoba. Milk control board. Annual report, 1947. Winnipeg, 1947. 23 p. (processed)
51. Saskatchewan. Milk control board. Annual report, 1947. Regina, 1948. 6 p. tabs. (processed)
52. Hundredweight method of paying for milk. E. G. Misner. Ithaca, 1946. (processed) (Cornell university agricultural experiment station A. E. 573)
53. Milchstatistik der Schweiz, 1946. Statistique laitière de la Suisse, 1946. (Landwirtschaftliches jahrbuch der Schweiz. Einundsechzigster jahrgang. Heft 8/9. Annuaire agricole de la Suisse. Quarantehuitième année de l'édition française. 8/9 fascicule. 1947. pp. 793-862)
54. D.I.S.I.—what is it? (International dairy industries society) (In The Canadian dairy and ice cream journal, February, 1948. pp. 40-47)

ECONOMICS

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61. How efficient is our agriculture. D. L. MacFarlane. (In Canadian countryman, March 6, 1948. pp. 7, 45)
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64. Major problems of United States foreign policy 1947: A study guide. Prepared by the staff of the International studies group of The Brookings institution. Wash., 1947. 303 p. (processed)

FARM LABOUR

65. Labor efficiency in harvesting hay. George F. Dow. Orono. 1947. pp. 153-222. figs. tabs. (Maine agricultural experiment station bulletin 453)
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67. Maatalouden työajan käyttö ja työntutkimus. Martti Sipilä. Helsinki, 1946. 496 p., appendices. (Suomen maataloustieteellisen seuran julkaisuja. Acta agralia Fennica. 66)
    English summary: Utilization of working hours and efficiency study in agriculture.

FEEDING AND FEEDING STUFFS

68. The sunflower (Helianthus annuus) S. D. Timson. Salisbury, 1947. 15 p. il. (Rhodesia. Dept. of agriculture bulletin no. 1415)
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FERTILIZERS

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74. Recommended fertilizer practices for 1948 . . . D. W. Thorne and H. B. Peterson. [In Farm and home science (Utah agricultural experiment station), Vol. 9, March 1948, no. 1. pp. 1, 17-19]
75. 1948 fertilizer supplies. Hearings before subcommittee of the Committee on agriculture, House of representatives . . . 1947. Wash., 1948. 180 p.

FOOD—FOOD PRESERVATION

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77. How far can Britain feed herself? Walter Elliot. (In The advancement of science, Vol. 4, no. 16, pp. 343-348)
78. U.S. Food and drug administration. Annual report, 1947. Wash., 1947. (Annual report of the Federal security agency, section 5. pp. 495-563)
79. The world food situation. John Kerr Rose. Wash., 1947. 111 p. (processed) (U.S. Library of congress. Legislative reference service. Public affairs bulletin no. 56)
80. The commercial freezing of fruit products. M. A. Joslyn and Leonora A. Hohl. Berkeley, 1948. 108 p. figs. tabs. General references sources: pp. 106-108. Literature cited: pp. 100-105. (California agricultural experiment station bulletin 703)
81. World food situation. (In D.I.S.I. bulletin no. 4, January, 1948. pp. 1-4)
82. The canning trade almanac, 1947. Annual compilation of the industry's statistics, laws, grades and other necessary reference data. Baltimore, "The canning trade," 1947. 290 p.

FORESTS AND FORESTRY

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87. Rehabilitation of areas stripped for coal. A. G. Chapman. Columbus, 1947. 14 p. (processed) (U.S. Dept. of agriculture. Forest service. Central States forest experiment station. Technical paper no. 108)

FORESTS AND FORESTRY—Continued

88. Studies of certain Scottish moorlands in relation to tree growth. London, H.M. stationery office, reprint, 1947. 111 p. figs. tabs. plates. (Great Britain. Forestry commission. Bulletin no. 15)
89. British Empire forestry conference, Fifth, Great Britain, 1947. Summary report, resolutions and reports of committees. London, H.M. stationery office, 1947. 56 p. At head of title: H.M. Forestry commission.
90. Seeding as a means of reforestation in the Northern Rocky Mountain region. C. S. Schopmeyer and A. E. Helmers. Wash., 1947. 31 p. figs. tabs. (U.S. Dept. of agriculture. Circular no. 772)
91. Tables for estimating cubic-foot volume of timber. Clement Mesavage. New Orleans, La., 1947. 70 p. (processed) (U.S. Dept. of agriculture. Forest service. Southern forest experiment station. Occasional paper no. 111)
92. Canadian society of forest engineers. Eleventh annual meeting of the Maritime section Halifax, 1948. Fredericton, 1948. 140 p. il. (processed)

GENETICS

93. Introduction to genetics and cytogenetics. Herbert Parkes Riley. New York, John Wiley & sons, inc., 1948. 596 p. figs. tabs. References: pp. 545-569.

HORTICULTURE

94. Daffodil and tulip year book, 1947. London, The Royal horticultural society, 1947. 133 p. figs. (No. 13)
95. The lily year book, 1947. London, The Royal horticultural society, 1947. 153 p. figs. (No. 11)
96. Vegetable growers association of America, inc., Annual report, 1947. Worthington, Ohio (1947) 236 p.
97. Potato production in the Northeastern and North Central States. P. M. Lombard and others. Wash., 1948. 70 p. figs. (U.S. Dept. of agriculture. Farmers' bulletin no. 1958, revised)
98. Growing cherries east of the Rocky Mountains. Leon Havis. Wash., 1948. 30 p. figs. (U.S. Dept. of agriculture. Farmers' bulletin no. 776, revised)
99. Currant culture in New Zealand. J. H. Watt. Wellington, 1947. 16 p. il. (New Zealand. Dept. of agriculture. Bulletin no. 282)
100. Grafting of fruit trees. A. R. Grainger. Wellington, 1947. 8 p. figs. (New Zealand. Dept. of agriculture. Bulletin no. 285)
101. Anyone can do grafting—Cleft grafting . . . W. H. Eyster. (In Organic gardening, March, 1948. pp. 40-43)
102. Gladiolus culture in British Columbia. J. H. Crossley and S. Arrowsmith, jr. Saanichton, B.C., Dominion experimental station, 1948. 14 p. (processed)
103. The Winnipeg flower garden, 1948. Winnipeg, Winnipeg horticultural society, 1948. 159 p. il.
104. Greenhouse management. A. G. R. Bouquet. Corvallis, 1948. 19 p. (processed) (Oregon state college. Extension service circular 499)
105. Growing garden peppers. A. G. R. Bouquet. Corvallis, 1948. 3 p. (processed) (Oregon state college. Extension service circular 500)

INSECTS—PESTS—INSECTICIDES

106. The detection and control of garden pests. G. Fox Wilson. London, Crosby Lockwood & son ltd., 1947. 194 p. plates.
107. A review of DDT formulations. R. D. Chisholm. Wash., 1948. 12 p. (processed) (U.S. Dept. of agriculture. Bureau of entomology and plant quarantine. E-742)
108. Handbook of insect enemies of flowers and shrubs. C. A. Weigel and L. G. Baumhofer. Wash., 1948. 115 p. figs. (U.S. Dept. of agriculture. Miscellaneous publication no. 626)
109. The flies that cause Myiasis in man. Maurice T. James. Wash., 1947. 175 p. figs. Literature cited: pp. 164-172. (U.S. Dept. of agriculture. Miscellaneous publication no. 631)
110. A synopsis of the larvaevorid flies of the genus Eudejeania. Curtis W. Sabrosky. Washington, 1947. (U.S. National museum. Proceedings. Vol. 97. no. 3215. 1947. pp. 141-156)
111. Entomological society of British Columbia. Proceedings. Vol. 44, 1947. Agassiz, 1948. 39 p. il.

INSECTS—PESTS—INSECTICIDES—Continued

112. Pest control agents. L. S. DeAtley. Columbus, Ohio, National farm chemurgic council, 1947. 11 p. (processed) (Chemurgic papers. 1947 series no. 5. No. 606)
113. Control of small animals in homes and gardens. W. R. Eadie and W. J. Hamilton, jr. Ithaca, 1947. 80 p. figs. (Cornell extension bulletin 729)
114. Pest control in commercial fruit plantings. Dwight Powell and others. Urbana, 1948. 40 p. (Illinois. University. College of agriculture. Extension service circular 623)
115. Studies on the control of wheat insects by dust. F. J. Gay and others. Melbourne, 1947. 38 p. (Australia. Council for scientific and industrial research. Bulletin no. 225)
116. Seasonal breeding and migrations of the desert locust (Schistocerca gregaria Forskål) in Western and North-Western Africa. U. Donnelly. London, British museum (Natural history), Anti-locust research centre, 1947. 43 p. il. (Anti-locust memoir 3)
117. Tobacco insects; suggestions for their control in Kentucky. W. A. Price. Lexington, 1947. 8 p. il. (Kentucky. University. College of agriculture. Agricultural extension division circular 437)
118. Changes in the insect fauna of a New England woodland following the application of DDT. Charles T. Brues. Harvard Forest, Petersham, Mass., 1947. 18 p. (Harvard forest papers. Vol. I, no. 1, 1947)
119. Controlling pests in stored products. R. T. Cotton. (In Northwestern miller. Vol. 233. no. 10. section one. March 9, 1948. pp. 19a-20a, 22a-23a)
120. Aphids feeding on violaceous plants in California. E. O. Essig. (In Hilgardia. Vol. 17, no. 18, November, 1947. pp. 597-617)
121. Biology and control of the pickleworm. B. B. Fulton. Raleigh, 1947. 27 p. (North Carolina agricultural experiment station technical bulletin no. 85)
122. List of processed publications issued by the Division of entomology, Dominion department of agriculture. Ottawa, Dept. of agriculture. Science service. Division of entomology, 1948. 6 p. (processed)

LIVE STOCK—BREEDING

123. Regional poultry research laboratory. Eighth annual report, 1947. East Lansing, Mich., U.S. Dept. of agriculture. Bureau of animal industry, 1947. 18 p. tabs. (processed)
124. Animal breeding and genetics research organisation. R. G. White. (In Agricultural progress. Vol. XXII (part 1) 1947. pp. 24-28)
125. Northern Ireland poultry breeding investigations. J. Morrison and R. W. Wale. (In World's poultry science journal. January-March, 1948. Vol. 4, no. 1. pp. 22-25)

MARKETING

126. South Africa. National marketing council on the marketing board, 1938 to 1946. Report. Cape Town, 1947. 206 p.

METEOROLOGY

127. Techniques of observing the weather. B. C. Haynes. New York, John Wiley & sons, inc., 1947. 272 p. figs. charts. Bibliography: pp. 199-205.

PASTURES AND MEADOWS

128. Emergency hay and pasture crops for Ontario. J. R. Weir and J. Laughland. (Guelph agricultural college) Toronto, 1948. 10 p. il. (Ontario dept. of agriculture bulletin 455)
129. Alfalfa for Manitoba. M. J. Tinline. (In The country guide, March, 1948. pp. 19, 32)

PHYTOPATHOLOGY

130. Pflanzliche infektionslehre, lehrbuch der allgemeinen pflanzenpathologie für biologen, landwirte, förster und planzenzüchter. Ernest Gäumann. Basel, verlag Birkhäuser, 1946. 611 p. il. figs. Literatur: pp. 573-583. (Reihe der experimentellen biologie. Band 1)
131. Diseases of strawberries. J. B. Demaree. Wash., 1948. 28 p. figs. (U.S. Dept. of agriculture. Farmers' bulletin no. 1891, revised)

PHYTOPATHOLOGY—Continued

132. Falling of wheat culm due to lodging, buckling, and breaking. Hurley Fellows. Wash. 1948. 16 p. figs. (U.S. Dept. of agriculture. Circular no. 767)
133. Virus diseases of plants; what they are and how they differ from fungus diseases. L. O. Kunkel. East Lansing, 1947. 19 p. figs. (Michigan state college. Agricultural experiment station circular bulletin 208)

PLANT BREEDING

134. Uniform alfalfa nurseries. Tenth and eleventh annual reports, 1946 and 1947. Beltsville, Md., U.S. Dept. of agriculture. Bureau of plant industry, soils, and agricultural engineering, 1947. 48 p. and 114 p. (processed)
135. Developmental morphology in some Indian millets. Khosla Shant. (In Proceedings of the Indian academy of sciences. Vol. XXIV. sec. B. no. 5. November, 1946. pp. 207-224)
136. Plant exploration and introduction service for India. (In Indian farming. Vol. VII, no. 10, October, 1946. pp. 448-451)
137. Growing plants without soil. Neil W. Stuart. (In Scientific monthly. Vol. LXVI. no. 4. April, 1948. pp. 273-282)

RESEARCH

138. Indian science congress. Proceedings of the Thirty-third session, Bangalore, 1946. Calcutta, Indian science congress association, Statistical laboratory, Presidency College, 1947. v.p. tabs.
139. The organisation of agricultural research. Sir John Fryer. (In Agricultural progress. Vol. XXII (part 1), 1947. pp. 9-19)
140. Through research to better farming. Morgantown, 1947. 48 p. figs. (West Virginia agricultural experiment station bulletin 330)
141. A paper on women in agriculture. Margaret R. Mackay. Edmonton, 1948. 14 p. (tpw.)
    A paper on opportunities for professional work for women in agriculture.

SOILS—SOIL CONSERVATION—IRRIGATION

142. Soil and the farmer. W. G. Ogg. (In Journal of the farmers' club. Part 2, 1948. pp. 14-27)
143. Results of tests on vegetated waterways, and method of field application. Maurice B. Cox and Vernon J. Palmer. Stillwater, 1948. 43 p. figs. tabs. (Oklahoma agricultural experiment station miscellaneous publication no. 12)
144. Crowded off the earth. Fairfield Osborn. (In The Atlantic monthly. Vol. 181, No. 3. 1948. pp. 17-23)
145. Research summaries, Parts I to VII. J. H. Stallings. Wash., U.S. Dept. of agriculture. Soil conservation service, 1945-1947. 7 pts. (processed)
146. Sir Robert Kane's soil survey of Ireland; the record of a failure. R. C. Simington and T. S. Wheeler. (In Journal of the Eire department of agriculture. Vol. XLIV, 1947. pp. 15-28)

VETERINARY MEDICINE

147. Sheep and lamb diseases. Wm. Lyle-Stewart. Newcastle, 1948. 48 p. (The Duke's fund. Fourteenth report of the trustees on research work into sheep and lamb diseases and allied problems)
148. Diseases transmitted from animals to man. Third edition. Thomas G. Hull. Springfield, Charles C. Thomas, 1947. 571 p. figs. tabs. References at ends of chapters.
149. Paratuberculosis, or pseudotuberulous enteritis of cattle—a study of Johne's disease. E. P. Johnson. Blacksburg, 1947. 15 p. figs. tabs. (Virginia agricultural experiment station bulletin 410)
150. South Australia. Institute of medical and veterinary science. Ninth annual report, 1946-1947. Adelaide, 1947. n.p.
151. Johne's disease. Aubrey B. Larsen. (In The Auburn veterinarian. Vol. III, no. 2. Spring, 1947. pp. 57-59, 82)

WEEDS

152. Weed control in linseed and flax. G. E. Blackman and K. Holly. (In Agriculture. Vol. LIV, no. 12. March, 1948. pp. 538-542)